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Example of systematic hierarchy and synonymy:
Family Cardiidae Lamarck, 1809
Subfamily Cardiinae Lamarck, 1809
Genus *Acanthocardia* Gray, 1853
(type species *Cardium aculeatum* Linné, 1758)

Cardium indicum Lamarck, 1819
(Fig. 1. A-D, Fig. 2. C)

Cardium hians Brocchi, 1814: p. 508, pl. 13, fig. 6 (non Spengler, 1799).
Cardium indicum Lamarck, 1819: p. 4.
Cardium (Cardium) indicum Lamarck – Fischer-Piette, 1977: p. 112, pl. 10, fig. 4 (type).

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... reported by Richardson & Smith (1965)
... as known in literature (Ross et al., 1993; Rosenberg, 1995, 1997; Micheline & Andriani, 2000)
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SALAS C., 1996. Marine Bivalves from off the Southern Iberian Peninsula collected by the Balgim and Fauna 1 expeditions. *Haliotis*, **25**: 33-100.
GRILL B. & ZUSCHIN M., 2001. Modern shallow- to deep-water bivalve death assemblages in the Red Sea - ecology and biogeography. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **168**: 75-96.
Boss K.J., 1982. Mollusca, in Parker S.P. (ed.), *Synopsis and Classification of Living Organisms*. Vol. 1. McGraw-Hill, New York: 945-1166.
CARTER J.G., CAMPBELL D.C. & CAMPBELL M.R. 2000. Cladistic perspectives on early bivalve evolution, in Harper E.M., Taylor J.D. & Crame J.A. (eds), *The Evolutionary Biology of the Bivalvia*. *Geological Society, London, Special Publications*, **177**: 47-95.
VOKES H.E., 1980. *Genera of the Bivalvia: a systematic and bibliographic catalogue (revised and update)*. Paleontological Research Institution, Ithaca, Edwards Brothers Inc., 307 pp.

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A new replacement name for the preoccupied fossil genus *Schizoproctus* Laghi, 2005 (Mollusca: Polyplacophora)

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Abstract
A new replacement name *Schizoproctochoiton* nom. nov., is hereby proposed to solve the homonymy between the polyplacophoran genus *Schizoproctus* Laghi, 2005 and the hexanaupliar genus *Schizoproctus* Aurivillius, 1885.

Key words
Replacement name, *Schizoproctochoiton*, *Schizoproctus*.

Riassunto
Si propone un nuovo nome sostitutivo *Schizoproctochoiton* nom. nov., per risolvere l'omonimia tra il genere poliplaceforo *Schizoproctus* Laghi, 2005 e il genere esanaupliano *Schizoproctus* Aurivillius, 1885.

Parole chiave
Nuovo nome, *Schizoproctochoiton*, *Schizoproctus*.

Introduction

The late Professor Laghi (pers. comm. Marco Taviani, July 22nd 2020) described in 2005 a new fossil genus *Schizoproctus*, typified by the new species *Schizoproctus prior* for a Triassic polyplacophoran from the Italian Dolomites. Unfortunately, the author was not aware that Aurivillius (1885: 247) already established a genus name *Schizoproctus*, typified by the new species *Schizoproctus inflatus* for a botryllophilid copepod that was found in an ascidian in arctic waters. In accordance with articles 60 & 60.3 of the ICZN (1999), the new replacement name *Schizoproctochoiton* nom. nov. is proposed for the junior homonym *Schizoproctus* Laghi, 2005, and the type species is here newly combined to: *Schizoproctochoiton prior* (Laghi, 2005).

Systematics

Class Polyplacophora Gray, 1821
Subclass Neoloricata Bergenhayn, 1955
Order Lepidopleurida Thiele, 1909
Suborder Lepidopleurina Thiele, 1909

Family unascertained (originally grouped under “Lepidopleuridae”)
Genus *Schizoproctochoiton* nom. nov. (gender: masculine, based on the Greek word χιτών) pro *Schizoproctus* Laghi, 2005 (non Aurivillius, 1885)

Type species: *Schizoproctochoiton prior* (Laghi, 2005) comb. nov. pro *Schizoproctus prior* Laghi, 2005

The generic concept is in accordance with Laghi (2005). Etymology: To honor the original name, the term “chiton” was added to the stem, indicating the polyplacophoran affinity.

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ICZN (International Commission on Zoological Nomenclature), 1999. *International Code of Zoological Nomenclature*. 4th edition. International Trust for Zoological Nomenclature, London, 232 pp.
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On the alleged presence of *Crisilla perminima* (Manzoni, 1868) in the Mediterranean Sea (Gastropoda: Littorinimorpha: Rissoidae), with notes on the taxonomy of *Alvania simulans* Locard, 1886

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Abstract

Crisilla perminima (Manzoni, 1868), a diminutive rissoid species living in Canary and Selvagens Islands (NE Atlantic), was reported from Sardinia. Based on the analyses of further material from Canary Islands and the Mediterranean Sea, as well as photographic comparisons by SEM, the Sardinian record is assigned to *Alvania simulans* Locard, 1886 which shows a certain degree of variability in sculpture and colour of the shell. *Crisilla perminima* is thus excluded from the Mediterranean malacofauna. The external soft parts of *A. simulans* are described for the first time and its taxonomic placement is discussed.

Key words

Mollusca, Caenogastropoda; distribution; Mediterranean Sea.

Riassunto

Crisilla perminima (Manzoni, 1868), un piccolo rissoida vivente nelle isole Canarie e Selvagens (NE Atlantico), è stato segnalato per la Sardegna. Sulla base dell'analisi di ulteriore materiale di provenienza atlantica e mediterranea, nonché di confronti fotografici al SEM, la segnalazione mediterranea viene attribuita ad *Alvania simulans* Locard, 1886. Conseguentemente, viene esclusa la presenza di *Crisilla perminima* nel Mar Mediterraneo. *Alvania simulans*, in alcune popolazioni, mostra un certo grado di variabilità per quanto riguarda sia il pattern cromatico sia la scultura, che si può presentare debole o addirittura assente. Le parti molli esterne di *A. simulans* sono descritte e la sua posizione tassonomica discussa.

Parole chiave

Mollusca, Caenogastropoda; distribuzione; Mare Mediterraneo.

Introduction

The family Rissoidae Gray, 1847 is a hyper-diverse group of microgastropods with a worldwide distribution, exceedingly represented in the European seas (Ponder, 1985; Criscione & Ponder, 2013 and herein). The genus-level taxonomy of the family was based almost entirely on shell characters until Ponder (1985) included anatomical data. Only recently, molecular tools have been employed to study the intrafamilial relationships among this group. These preliminary results showed that Rissoidae, as generally understood, are polyphyletic (Criscione & Ponder, 2013) and many traditional genera should be reconsidered and redefined (Criscione et al., 2017), among them the genus *Crisilla* Monterosato, 1917. For instance, the two *Crisilla* examined (unfortunately the type species was not included) nest in *Alvania* s. l.

Crisilla was established for a group of rissoid species characterized by shells with a faint sculpture and darker spots; the author included *Turbo semistriatus* Montagu, 1808, *Cingula beniamina* Monterosato, 1884 and other European unmentioned species (Monterosato, 1884; 1917). Ponder (1985), in his global revision of Rissoidae, stressed the similarities between *Crisilla* and *Alvania* Risso, 1826 and maintained *Crisilla* as a subgenus of *Alvania*, relying upon few conchological features,

such as the absence of apertural varix and faint axial sculpture, while anatomical characters substantially overlap with those of *Alvania* s. l. Subsequently Bouchet & Warén (1993) raised it to a full generic status, again on the mere shell morphology. Currently few species have been investigated anatomically (Ponder, 1985; Templado & Rolán, 1994; Scuderi & Amati, 2013) and even less on molecular bases (Criscione et al., 2017). The genus itself is therefore poorly defined according to modern standards and its real status and boundaries are unclear. It is currently characterized on conchological traits, detailed by Oliver et al. (2019). As a consequence, its composition is quite in flux, e.g. some species have been recently transferred to *Crisilla* on shell characters (Van Dingenen et al., 2016; Appolloni et al., 2018; Oliver et al., 2019).

Crisilla has, with one exception, a Mediterranean and E Atlantic distribution and includes 39 recent species (MolluscaBase, 2018). A typical pattern of mutual exclusion in the geographical distribution appears between "Macaronesian" and Mediterranean species (Oliver et al., 2019), apparently with the exception of *Crisilla perminima* (Manzoni, 1868). This species has a distribution limited to the Canary and Selvagens Islands (Verduin, 1984; Templado & Rolán 1994; Albuquerque et al., 2009; Rolán et al., 2011), the only other record consists in few empty shells found in a shell-grit from NW Sardinia

(Tisselli & Giunchi, 2005) with no subsequent findings known from Mediterranean Sea. Segers et al. (2009) and Oliver et al. (2019) questioned the identity of Sardinian finding. Here “Mediterranean *C. perminima*” and further material have been reexamined, compared with Atlantic *C. perminima* and similar species, and its status, in relation to *Alvania simulans* Locard, 1886, is clarified.

Materials and methods

Dried material was collected from bioclastic bottoms by SCUBA diving or obtained through the analysis of by-catch of commercial trawling. Living specimens were collected by brushing the surface of stones. Comparisons were done with material figured in literature and samples from several localities (see below). Analyzed material is currently preserved in private collections. Shells were examined through Lomo MBC-10 and Konus Crystal-45 stereomicroscopes, photographed with Canon EOS 400D and Nikon Coolpix 990 cameras, while measurements were carried out by means of an eyepiece micrometer. Protoconch whorls were counted according to Verduin (1977). Shell and details were examined with both XL30 and Quanta 200 Scanning Electron Microscope (SEM) in the Centro de Apoyo Científico y Tecnológico a la Investigación (CACTI) - University of Vigo, after air drying and mounting on SEM stubs. Live collected specimens of *A. simulans* were observed under the stereomicroscope and the features of head-foot recorded by colour drawings. Updated taxonomy and nomenclature follow MolluscaBase (2020).

The following abbreviations and acronyms are used: AP: Attilio Pagli collection (Empoli); CB: Cesare Bogi collection (Livorno); IN: Italo Nofroni collection (Roma); LR: Luigi Romani collection (Lucca); MTS: Maria Teresa Spanu collection (Alghero); DS: Danilo Scuderi collection (Catania); MT: Morena Tisselli collection (Ravenna); SB: Stefano Bartolini collection (Firenze).

Material examined

Crisilla iunoniae (Palazzi, 1988): 2 shells, El Porís, (Tenerife, Canary Islands, Spain), 20 m, in MT (ex IN). *Crisilla perminima* (Manzoni, 1868): 1 shell, El Porís, (Tenerife, Canary Islands, Spain), 20 m, in CB. 2 shells, El Porís, (Tenerife, Canary Islands, Spain), 20 m, in MT (ex IN). 5 shells, La Caleta (Tenerife, Canary Islands, Spain), 0.5 m, in LR (Fig. 1. J). 6 shells, Tenerife (Canary Islands, Spain), in MT. “Mediterranean *Crisilla perminima*”: 4 shells, Grotta Verde, Capo Caccia (Alghero, Sardinia, Italy), 25 m (Figs. 1. A-D), in MT. 2 shells, Grotta Madonnina, Alghero (Sassari, Sardinia, Italy); 1 shell, Grotta Galatea, Alghero (Sassari, Sardinia, Italy) (Fig. 1. F); 1 shell, Grotta di Nettuno, Alghero (Sassari, Sardinia, Italy) (Fig. 1. E); 1 shell, Alghero (Sassari, Sardinia, Italy), 32 m (Fig. 1. G), all in MTS. 4 shells, Capo Caccia (Alghero, Sardinia, Italy), 32 m; 1 shell, Scilla (Reggio Calabria, Italy), 40 m, all in AP. 4 shells, Punta Campanella (Gulf of Naples, Italy), 40 m (Figs. 2 K, L);

1 shell, Rio Marina (Elba Island, Livorno, Italy), 30 m, all in SB. *Alvania simulans* Locard, 1886: 35 shells, Cannizzaro (Catania, Sicily, Italy), 43 m; 45 shells, La Herradura (Alboran Sea, Spain), 35 m; 40 shells, Punta Campanella (Gulf of Naples, Italy), 40 m, all in SB (Figs. 2. A-G, I-J); 1 shell, Alghero (Sassari, Sardinia, Italy), 32 m, in MTS; 10 living specimens, Giovanni Li Cuti - Catania, (Sicily, Italy), 4 m, on rocky substrate (biocoenosis of photophilic algae), in LR and DS (Fig. 2. H).

Discussion and conclusions

The identity of the mediterranean specimens assigned to *Crisilla perminima*

Tisselli & Giunchi (2005) assigned some shells collected in Sardinian submarine caves to *Crisilla perminima* relying on the similar shell colour pattern, size and outline, and asserting that protoconch size and sculpture match with those reported by Verduin (1984) for that species. No actual specimen of the true *C. perminima* was examined for direct comparison. Here these shells, reexamined relying on SEM images, and compared with further material both from the Mediterranean Sea and Canary Islands, are proven not to belong to this species. The “Mediterranean *C. perminima*” is distinct from the true *C. perminima* by: more conical outline, proportionally larger aperture, lower H/W ratio, whorls more convex and regularly curved (Figs. 1. D, E). A spiral microsculpture, though very weak, is detectable by SEM images. The protoconch show some crucial differences: a larger size (average diameter 350 µm, in the measured shells), a more inflated form, microsculpture consisting of irregular and flattened cords (sometimes simulating a zigzag), roughly wide as the interspaces, in number of 10-13 (Figs. 1. B, C). The true *C. perminima*, conversely, is smaller, more elongated (higher H/W ratio), with a proportionally smaller aperture, whorls slightly concave in the adapical part (Fig. 1. J). The teleoconch sculpture is almost absent, except few weak spiral furrows in the periumbilical area, and there’s no spiral microsculpture (Fig. 1. H). The protoconch has an average total diameter of 250 µm, and is ornamented with 7-9 spiral grooves, regularly spaced, and far narrower than the interspaces (Fig. 1. I) (Oliver et al., 2019). The previous examination, made by exclusive use of a stereomicroscope, explains the inaccurate protoconch measurements and the incorrect detection of microsculpture details by Tisselli & Giunchi (2005). Further confusion arose from the uncorrect synonymization of *Crisilla spadix* (Watson, 1897) with *C. perminima* that led to the erroneous depiction of the former under the latter name (Ponder, 1985; Verduin, 1988; Palazzi, 1988; Segers et al., 2009; Oliver et al., 2019). On the contrary the protoconch features of the “Mediterranean *Crisilla perminima*” match perfectly those of *Alvania simulans* Locard, 1886, in size (350 µm vs. 360 µm, average, in the measured shells) and sculpture (10-13 vs. 10-14 cords) (Figs. 2. E, F). The shell size is on average slightly lower than

it is in *A. simulans* (maximum height 1.5 mm), but however higher the *C. perminima* (1.1-1.2 mm in the measured shells).

In light of this, shells of *A. simulans* show a degree of variability in sculpture and colour patterns larger than previously recognized (Giannuzzi Savelli et al., 1997;

Gofas et al., 2011; Scaperrotta et al., 2011). Some populations include specimens with attenuate to almost absent sculpture; some of those show quite typical colour patterns (Figs. 2. I), others a uniform brownish hue except two white bands at the periphery of the whorls and on the umbilical area (Fig. 2. L). However, there are inter-

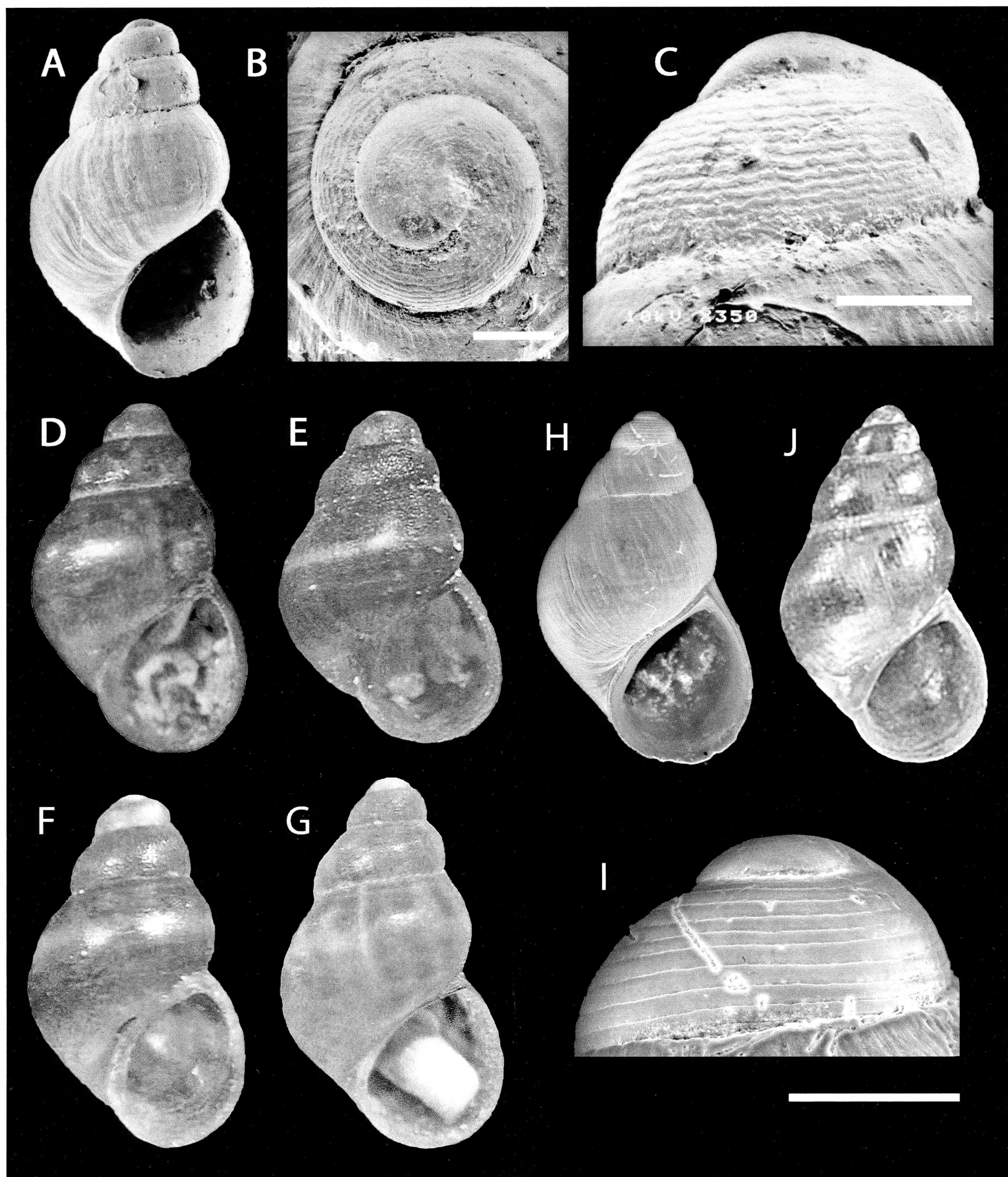


Fig. 1. A-G. "Mediterranean *Crisilla perminima*" = *Crisilla simulans* (Locard, 1886). **A-C.** 1.5 mm, Capo Caccia (Sardinia); **D.** 1.4 mm, Capo Caccia (Sardinia), from Tisselli & Giunchi (2005) modified; **E.** 1.3 mm, Grotta di Nettuno, Alghero (Sardinia); **F.** 1.4 mm, Grotta Galatea, Alghero (Sardinia); **G.** 1.6 mm, Alghero (Sardinia). **H, J.** *Crisilla perminima* (Manzoni, 1868). **H, I.** 1.1 mm, La Palma (Canary Islands), from Oliver et al. (2019) modified. **J.** 1.2 mm, Tenerife (Canary Islands).

Fig. 1. A-G. "*Crisilla perminima* del Mediterraneo" = *Crisilla simulans* (Locard, 1886). **A-C.** 1,5 mm, Capo Caccia (Sardegna); **D.** 1,4 mm, Capo Caccia (Sardegna), da Tisselli & Giunchi (2005) modificato; **E.** 1,3 mm, Grotta di Nettuno, Alghero (Sardegna); **F.** 1,4 mm, Grotta Galatea, Alghero (Sardegna); **G.** 1,6 mm, Alghero (Sardegna). **H, J.** *Crisilla perminima* (Manzoni, 1868). **H, I.** 1,1 mm, La Palma (Isole Canarie), da Oliver et al. (2019) modificato. **J.** 1,2 mm, Tenerife (Isole Canarie).

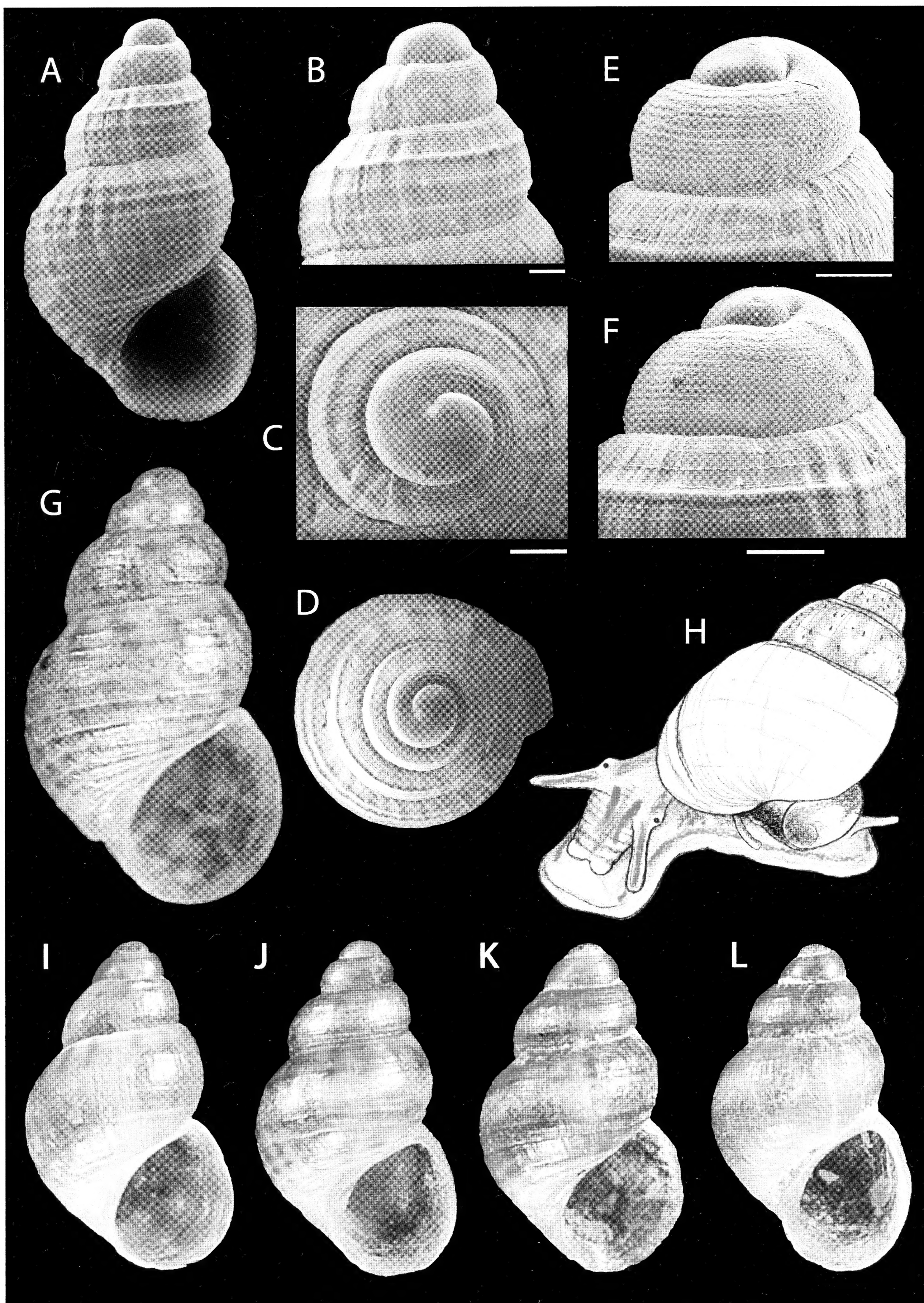


Fig. 2. A-L. *Crisilla simulans* (Locard, 1886). All, except **H**, from Punta Campanella (Naples) **A-F**. 1.7 mm,; **G**. 1.8 mm; **H**. San Giovanni Li Cuti (Catania, Sicily), drawing of external soft parts; **I**. 1.5 mm; **J**. 1.5 mm; **K**. 1.5 mm; **L**. 1.5 mm. Scale bars = 100 µm.

Fig. 2. A-L. *Crisilla simulans* (Locard, 1886). Tutte, eccetto **H**, da Punta Campanella (Napoli) **A-F**. 1,7 mm,; **G**. 1,8 mm; **H**. San Giovanni Li Cuti (Catania, Sicilia), disegno delle parti esterne molli; **I**. 1,5 mm; **J**. 1,5 mm; **K**. 1,5 mm; **L**. 1,5 mm. Unità di misura = 100 µm.

mediate specimens connecting these forms to the typical one (Figs. 2. J, K). The “Mediterranean *Crisilla perminima*” and the “smooth banded” form of *A. simulans*, substantially overlap in all respects, and should be considered conspecific. *C. perminima* must therefore be excluded from the recent Mediterranean malacofauna.

The taxonomic status of *Alvania simulans*

The specific identity of *A. simulans* is well established since Verduin (1984) summarized its complex taxonomical-nomenclatural history and stabilized its status by selecting and describing a lectotype and paralectotypes. Its morphological characters (based solely on the shell), regarded as fairly constant, are here reconsidered in the light of the new data. Hence we provide a redescription of the shell, adding a first general description of external soft parts.

Shell small (up to 1.8 mm), ovate-conical, rather thin but not fragile, semitransparent. Last whorl large, about 65-70% of shell height. Protoconch yellowish, paucispiral, prominent, consisting of 1.2-1.3 whorls, average diameter 350 µm (Figs. 2. B, C). Nucleus apparently smooth followed by ca. half whorl ornamented with a dense irregular sculpture (Fig. 2. F) which gradually turns in 10-14 irregular and flat cords, roughly wide as the interspaces (Fig. 2. E). Protoconch-teleoconch border simple, sometimes marked by a shallow depression of the spire (Fig. 2. C). Teleoconch consisting of 2.7-3 regularly convex whorls (Figs. 2. A, G). Suture evident but not deep. Aperture drop-shaped, with parietal and columellar tracts gently curved. Outer lip rounded, with no evident external varix, yet sometimes slightly thickened. No internal lirae. Seen from aside, the edge of the outer lip is orthocline, slightly curved in the middle. Umbilical chink absent or very narrow. Spiral sculpture predominant, typically consisting of 10-11 spiral cords on the last whorl, roughly equidistant and narrower than interspaces. Some spirals can be stronger than others, generally the adapical one or the one at the whorl periphery, the former is quite spaced from the suture, defining a faint subsutural ramp (Fig. 2. D). Axial sculpture, besides growth lines, absent or weak, consisting of tenuous ribs, sometimes forming blunt inconspicuous tubercles at the intersection with spirals. Spirals can be more or less obsolete in the middle area of the whorl and almost absent in some specimens. Surface covered with spiral microsculpture of very thin treads, more evident in the adapical part of the whorls (Figs. 2. B, F). Background colour yellowish or whitish. Typical pattern of longitudinal and irregular series of quadrangular chestnut-hued spots. Subsutural spots larger and often elongated, particularly intense near the aperture. Aperture and periumbilical area dirty white in colour. Some specimens have spot pattern indistinct or absent, with background colour more or less brownish except the periumbilical area and a white peripheral band.

External soft parts have general rissoid-like appearance (Fig. 2. H). Background colour pearl-whitish with nu-

merous minute shiny spots scattered all over the entire body. Snout short, bilobed with a thin brownish strip running on its dorsal part. Cephalic tentacles yellow as well as glandular areas on the snout, between and just behind the eyes. Foot bordered by a yellow strip except the most anterior part. Opercular disc, which has an almost black contour, bordered by a short yellow band. Two pallial (anterior and posterior) tentacles and one slender metapodial tentacle. Operculum thin, transparent, paucispiral, with eccentric nucleus.

Alvania simulans can be therefore regarded as a quite variable species whose features are atypical for the genus. Indeed, in recent literature it has been assigned to both *Alvania* or *Crisilla*, (e.g. Poppe & Goto, 1991; Gofas et al., 2011; Scaperrotta et al., 2011 vs. Sabelli et al., 1990; Giannuzzi Savelli et al., 1997; Repetto et al., 2005; Cosignani & Ardovini, 2011; MolluscaBase, 2020a). Verduin himself (1984), yet retaining it in *Alvania*, treated *A. simulans* in his review of the genus *Cingula* s.l. (then including many *Crisilla* species). More recently, Amati & Oliverio (2020) suggest possible affinities with *Crisilla*. Relying on conchological features, this species departs from *Alvania* and approach to *Crisilla* for the small size, general outline and absence of a conspicuous axial sculpture, on the other hand it differs from species regarded as *Crisilla* by the absence of subsutural furrows, broad and flat spiral cords, and microsculpture without spiral elements (Oliver et al., 2019). Moreover *A. simulans* has a single metapodial tentacle, character which is at odd with the diagnosis of both *Crisilla* and *Alvania* (Ponder, 1985; Templado & Rolán, 1994). This unusual combination of characters is a further hint of the artificial status of *Alvania* and *Crisilla* genera, as currently conceived, and confirms the need of a deep revision of these groups.

A. simulans shows similarities with some recent taxa mostly assigned to *Crisilla*, among them: *Rissoa watsoni* Schwartz in R. B. Watson, 1873; *Cingula basteriae* Moolenbeek & Faber, 1986; *Crisilla graxai* Templado & Rolán, 1994; *Crisilla luquei* Templado & Rolán, 1994. These species share the lack of conspicuous axial sculpture, narrow spiral cords, presence of a spiral microsculpture, similar protoconch characters (Moolenbeek & Faber, 1986; Templado & Rolán, 1994; Moolenbeek & Hoenseelaar, 1998; Van Dingenen et al., 2016). They could represent a clade whose relationships within the rissoids will have to be settled in the frame of wide molecular and anatomical investigations. In the meanwhile, following the current morphological standards, this one and allied species would be better placed in *Crisilla* Monterosato, 1884.

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On the alleged presence of *Crisilla perminima* (Manzoni, 1868) in the Mediterranean Sea (Gastropoda: Littorinimorpha: Rissoidae)

An agonistic encounter in the wild between two adult males of *Octopus vulgaris* (Cephalopoda: Octopodidae)

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Abstract

The confrontation in the wild between two large males (ca. 8 kg each) of *Octopus vulgaris* is described by a sequence of 13 underwater photographs and their detailed account. The event occurred in the North-East Atlantic off the coast of Portugal, at 17.5 m of depth. The agonistic encounter was started when an individual, the initiator, aggressively approached another individual, the reactor, busy getting some food from a ghost octopus trap. After showing each other their well-expanded suckers, including the male dimorphic large suckers on lateral arms, at very close distance, they grappled into an entanglement that involved all their arms. The grappling lasted for less than a minute, after which the octopuses released each other. The initiator stayed in place whereas the reactor left the ground, which fact showed that the latter was seemingly the loser. No evident severe injury was suffered by the loser. The colour and body posture patterns of each opponent are described in the light of behavioural accounts by literature sources, in the context of 'central programs.' In particular, the initiator kept an overall darker colouration than the reactor. This is possible the best described agonistic encounter between two adult males of *O. vulgaris*.

Key words

Cephalopoda, *Octopus vulgaris*, behaviour, agonistic encounter, body pattern, North-East Atlantic.

Riassunto

Scontro in ambiente naturale tra due maschi adulti di Octopus vulgaris (Cephalopoda: Octopodidae)
Viene descritto uno scontro in ambiente naturale tra due grossi maschi di *Octopus vulgaris* (ciascuno di ca. 8 kg) per mezzo di una sequenza di 13 fotografie subacquee, commentate in tutti i particolari. L'evento ebbe luogo nell'Atlantico nord-orientale, al largo della costa portoghese, a 17,5 m di profondità. Lo scontro ebbe inizio quando uno dei due individui, 'assalitore', si avvicinò con fare aggressivo all'altro, 'aggregato', impegnato in quel momento a procurarsi del cibo da una nassa per polpi abbandonata sul fondo. I polpi, giunti a brevissima distanza l'uno dall'altro, dapprima esibirono reciprocamente le ventose completamente espanse, comprese quelle grandi delle braccia laterali, tipiche dei maschi. Quindi, impegnando entrambi tutte le loro braccia, si avvinghiarono in un serrato intreccio. Il corpo a corpo durò meno di un minuto, dopodiché i polpi si distaccarono. L'assalitore rimase sul posto, mentre l'aggregato abbandonò il campo, a riprova della sua sconfitta. Il corpo del perdente non mostrava segni evidenti di ferite gravi. Vengono descritti sia i cambi di colore della pelle dei due avversari sia i loro moduli posturali durante tutte le fasi dello scontro, alla luce delle descrizioni comportamentali riferite dalla letteratura, nel contesto dei 'programmi centrali'. In particolare, l'assalitore conservò, durante tutto lo scontro, una colorazione più scura di quella dell'aggregato. Quella qui presentata è, per quel che ci è dato sapere, la più accurata descrizione di uno scontro in ambiente naturale tra due maschi adulti di *O. vulgaris*.

Parole chiave

Cephalopoda, *Octopus vulgaris*, comportamento, scontro, moduli corporei, Atlantico nord-orientale.

Introduction

The common octopus, *Octopus vulgaris* Cuvier, 1797 *sensu stricto* (Cephalopoda: Octopodidae), inhabits the Mediterranean Sea and the North-eastern Atlantic Ocean; it is a benthic species that lives from 0 to 250 m of depth, but typically in water shallower than 100 m, on rocky, sandy or muddy substrates (Norman et al., 2013). It is, most probably, the best-known cephalopod and the most studied one in the wild (e.g. Hanlon & Messenger, 2018; Hernández-Urcera et al., 2014) as well as in captivity, both in exhibition aquaria (e.g. Lee, 1875) and in experimental settings (e.g. Packard, 1961). Research has shown that this cephalopod has a broad behavioural and neural plasticity supported by high cog-

nitive capabilities (Tricarico et al., 2014). Incidentally, its eyesight is excellent (Young, 1971), so visual communication is important for *O. vulgaris* (e.g. Borrelli et al., 2006; Tricarico et al., 2011).

Post-settlement individuals of this species are known to be solitary animals (Hanlon & Messenger, 2018). Little is known about the interactions between individuals of this species in the wild, i.e. what happens when two of them meet occasionally, since, as Aronson (1991: 249) stated, "Octopuses are notoriously difficult to study in the field." Apart when an octopus succeeds in escaping a much larger one, in general three types of close encounters may be envisaged for *O. vulgaris*:

mating: between a male and a female apt to copulate; the meeting starts with the male displaying its enlarged

suckers of the 2nd and 3rd arms to the female; then copulation follows and ends with the male retrieving its hectocotylus and fleeing away soon after completion of spermatophores transfer (Packard, 1961; Wells & Wells, 1972; Hanlon & Messenger, 2018);

cannibalism: between two octopuses largely differing in size (at least 4:1) and the larger one succeeds in seizing the smaller one (Hernández-Urcera et al., 2014, 2019; Bello & D'Alessandro, 2017; several additional cases of cannibalistic behaviour in the Mediterranean Sea have been communicated to one of the present authors, G.B.); confrontation: an agonistic physical confrontation between two individuals of about the same size.

The latter type of encounter is accurately documented for the first time here, to the best of the authors' knowledge.

Materials and methods

The agonistic encounter between two adult males of *Octopus vulgaris* was occasionally observed and photographed by one of the present authors (V.A.), during a routine underwater photographic excursion. The dive was carried out in the diving spot "Jardim das Gorgónias" off the village of Sesimbra (Setúbal District, Portugal, some 50 km south of Lisbon), on the 24th of August 2013 at 10.30 a.m.; depth: 17.5 m, water temperature: 15 °C. The pictures were taken by a Sea life DC500 camera (standard housing) with a Sea life SL 960D digital external flash.

A sequence of 21 photographs was taken, on whose examination and interpretation the present results are based. Only 13 photos are shown in the present note, since the remaining ones do not add any further significant information. Each photograph (Figs 1-13) is also described in words for a better appreciation.

The *O. vulgaris* fight occurred on a sandy bottom close to a *covo*, a typical Portuguese iron frame plastic mesh

octopus trap, 40x44x25 cm in size and 4 cm mesh size, with an upper funnel entrance for the target animal and a bait basket (yellow with white cover) by the entrance (Erzini et al., 2008). In particular, the fishing gear in the photographs was a ghost trap, that is one that had been lost by fishermen some time before, as shown by its decayed conditions and by the missing line (Erzini et al., 2008); hence there was no bait in the bait-basket.

The two octopuses are named Octo-1 and Octo-2, in order of appearance. They were really huge and of about the same size. The estimated mantle length of Octo-1, by comparison with the trap size, was about 30 cm (conservative estimate), which corresponds to a conservative estimated weight of 8.1 kg according to the regression equation in Merella et al. (1997).

The term 'pattern' is used to mean the appearance of either octopus at one moment (Packard & Sanders, 1971). Most patterns, as defined by Packard & Sanders (1971), Mather (1998) and Borrelli et al. (2006), are nicely depicted in the latter work; additional descriptions are given by Mather & Alupay (2016). The terms 'initiator' and 'reactor' (Scheel et al., 2016) were used to indicate the attacking and the attacked individuals, respectively.

Results

The agonistic interaction between the male octopuses is here documented by a sequence of 13 underwater photographs (Figs. 1-13) that contributes to decode the octopuses behaviour during the encounter, from the very onset (Fig. 1) to its non-lethal end (Fig. 13).

The phases of the encounter are described according to the photographic sequence.

Fig. 1 – Octo-1 is on a trap, grasping it at one corner with its lateral arms; the right arms are in the foreground and the left ones, barely visible, are in the background. Body coloration is in the 'uniform phase,' a



Fig. 1. The first of two octopuses (*Octopus vulgaris*) – alias Octo-1 – grasps a ghost trap on a sandy bottom.

Fig. 1. Il primo dei due polpi (*Octopus vulgaris*) – denominato Octo-1 – è su una nassa abbandonata sul fondo sabbioso.



Fig. 2. Octo-1 inserts a couple of arms into the trap probably looking for food.

Fig. 2. Octo-1 ha infilato un paio di braccia nella nassa probabilmente alla ricerca di cibo.



Fig. 3. Octo-1 is sitting on the trap; it looks quite relaxed.

Fig. 3. Octo-1, sempre sulla nassa, appare piuttosto rilassato



Fig. 4. The second octopus – alias Octo-2 – is standing on a rocky outcrop, at some 5 m away from Octo-1.

Fig. 4. Il secondo polpo – denominato Octo-2 – siede su una roccia a ca. 5 m da Octo-1.

chronic pattern (Packard & Sanders, 1971), and posture is 'stand tall' (Mather & Alupay, 2016).

Fig. 2 – Then Octo-1 inserts its first right arm and another one (first left?) into the trap, likely trying to get some food item from it.

Fig. 3 – The octopus looks quite relaxed while sitting on the trap.

Fig. 4 – Octo-2 is standing on a rocky outcrop, some 5 metres away from Octo-1. It is dark coloured with dark arm bars, a pattern typical of when in presence of another octopus (Packard & Sanders, 1971; Mather & Alupay, 2016), with head and eyes raised and the inter-brachial web partly spread (Borrelli et al., 2006).

Fig. 5 – Then, Octo-2 leaves the rock and moves towards Octo-1, thus initiating the confrontation. Octo-1 in turn reacts by leaving the trap (which now is about 1 m behind it, on the left) and moving towards the initiator.

The octopuses are entering a 'fighting display' (Packard & Sanders, 1971), with the 'oppose' pattern (Mather, 1998). They face each other with their suckers extended, especially in Octo-1, i.e. the reactor, almost suckers to suckers (Packard & Sanders, 1971; Mather, 1998); their right arms are spread apart from the left arms, each dorsal arm closely aligned to the dorso-lateral arm. The enlarged and noticeably displayed suckers on the lateral arms of both individuals show that they are males. The initiator's overall colouration is darker than the reactor's; each respective colouration is quite uniform all over the body. The reactor is somewhat holding back, its head and proximal part of arms slightly tilted back, whereas the initiator goes on moving towards it.

Fig. 6 – Octo-2 assaults Octo-1, striking it with its dorsal arms (only the left one visible in the photograph). Both

Fig. 5. Octo-2, the initiator, (on the right) left the rock and moved towards Octo-1, the reactor (on the left); the latter, in turn, left the trap and went towards the initiator.

Fig. 5. Octo-2, l'assalitore, (sulla destra) si è spostato dalla roccia verso Octo-1, l'aggregato, (sulla sinistra) che a sua volta si è mosso verso l'assalitore.



Fig. 6. Octo-2 (on the right) assaults Octo-1 (on the left) striking it with its dorsal arms (only the left one visible).

Fig. 6. Octo-2 (sulla destra) aggredisce Octo-1 (sulla sinistra) con le braccia dorsali (si vede solo il sinistro dei due).



individuals keep their mantles and heads bent backwards. The body colouration of Octo-2 keeps much darker than Octo-1.

Fig. 7 – Octo-2 tries to envelop Octo-1 with its arm web ('webover' of Mather, 1998). Some Octo-1's arms succeed in keeping out of the web envelop.

Fig. 8 – Octo-1 (mantle in the foreground, left; lighter coloured) is fighting back and, in turn, grasps Octo-2 (mantle close to the trap, in the background; darker coloured) with some of its own arms. Some arm tips of both animals reach the mantle of the antagonist.

Fig. 9 – Soon after, the octopuses make an intricate grapple where it is difficult to distinguish which is which. Neither cephalopod appears to overwhelm the other, that is to say neither succeeds in trapping the other in its own arm web.

Fig. 10 – After which, the octopuses begin to disengage.

The upper one (according to the mantle position in the photograph (Octo-2?) displays extended supraocular branched papillae (Borrelli et al., 2006). The mouth of the lower one (Octo-1?) is visible in the foreground and presently is not involved in any offensive/defensive action.

Fig. 11 – The octopuses go on disengaging from each other: now the contact between them involves their arms only. Note one freshly wounded arm (right lower corner of photograph).

Fig. 12 – Eventually the fighters (Octo-2 in the foreground, Octo-1 in the background) loose each other, while keeping watch of each other. The large suckers in Octo-1 are maximally covered (white surface indrawn); those of Octo-2 are not visible. As for the overall colouration, it is uniform in Octo-1 and broad trellis-like mottled in Octo-2.



Fig. 7. Octo-2 tries to envelop Octo-1 with its arm web.

Fig. 7. Octo-2 tenta di avvolgere Octo-1 col proprio apparato brachiale.



Fig. 8. Octo-1 (mantle in the foreground, right) fights back and, in turn, grasps Octo-2 (mantle close to the trap, in the background) with some of its own arms.

Fig. 8. Octo-1 (mantello a destra, in primo piano) si difende e a sua volta afferra con le proprie braccia Octo-2 (mantello vicino alla nassa, in secondo piano).

Fig. 9. The octopuses make an intricate grapple where it is difficult to distinguish which is which.

Fig. 9. I due polpi sono avviluppati in un intrico di braccia dove è difficile distinguerli.



Fig. 10. The opponents are disengaging from each other; the fight is coming to an end.

Fig. 10. I due avversari sono in fase di disimpegno; la lotta volge al termine.



Fig. 11. The opponents go on further disengaging from each other; note a freshly wounded arm (right lower corner of photograph).

Fig. 11. I due avversari si disimpegnano ulteriormente; notare un braccio ferito nella lotta (in basso a destra).



Fig. 13 – At the end of the encounter, Octo-1 (in the background, left) with head and eyes flat is leaving the fight ground crawling backwards. Octo-2 (in the foreground, right) stands still, its mottled colouration dissolving.

The event covered in the photographic sequence lasted little more than a minute; the physical contact between the animals lasted slightly less than one minute. A short while after Octo-1 left the fight ground, Octo-2 moved towards the trap. Meanwhile, other divers drew close to it so that the latter flew back to the rock outcrop. Incidentally, while the octopuses were fighting, some sparid fish, namely *Spondyllosoma cantharus* (Linnaeus, 1758) (Figs 11, 12) and *Sparus aurata* Linnaeus, 1758 (Fig. 12) were swimming closely about them, seemingly to take advantage of the skin bits coming off the cephalopod bodies during their struggle.

Discussion

The event documented here is a case of antagonistic encounter between two adult males of *Octopus vulgaris*, which escalated into a fight, i.e. body grappling. As stated by Borrelli et al. (2006), published reports of overt fighting in *Octopus vulgaris* are scanty. The photographic sequence clearly shows that Octo-2 was the initiator of the fight: this was the octopus to display the ‘arm dark bars,’ hence an overall reddish-brown overall colouration (Figs 4-7), the one to move towards the other conspecific, to start the ‘oppose’ and, soon after, the ‘webover’ patterns; the one to display a trellis-like ‘broad mottled’ colouration during the fight (Figs 8-12). On the other side, Octo-1 exhibited reactor’s patterns: lighter colouration and (partial) ‘retro-flex’ pattern (Fig. 5) (Scheel et al., 2016). Interestingly, Octo-1, the reactor, did not run away but moved to-



Fig. 12. The fighters eventually loose each other (Octo-2 in the foreground, Octo-1 in the background).

Fig. 12. I contendenti infine si distaccano (Octo-2 in primo piano, Octo-1 in secondo piano).



Fig. 13. Octo-1 (in the background, left) leaves the fight ground crawling backwards; Octo-2 (in the foreground, right) stands still.

Fig. 13. Octo-1 (a sinistra in secondo piano) abbandona il campo, mentre Octo-2 (in primo piano) rimane sul posto.

wards Octo-2, although with a seemingly submissive attitude – that is with reactor's patterns – maximally displaying its male large suckers, as Octo-2 also did. In summary, the reactor appeared ready to fight back anyway. Contrary to this observation, anecdotal accounts refer that when an octopus meets or is met by a much larger individual it runs away (Bello, 2017).

The attack by a male octopus on another male of about the same size is not easily explained. According to Hufard (2005), the potential causes for male-male agonistic behaviours are predation, competition for mate, competition for den. The hypothesis of a predatory aggression by the initiator can be safely discarded, since in all documented cannibalistic actions the predator is much larger, four- to fivefold, than the potential prey (Hernández-Urcera et al., 2014, 2019; Bello & D'Alessandro 2017), which is not the present case. Moreover, the fact that neither octopus succeeded in overwhelming the other confirms, in our opinion, that the here described event was not a preying act. Likewise, neither competition for den nor for mate can be promptly invoked: as for the former, the reactor was attacked while far away (more than 5 m) from any potential den of the initiator; as for the latter, *O. vulgaris* males are not known to directly compete for females and, besides, no potential female mate was visible in proximity of the two fighting males. For sure, the initiator's action was triggered by the appearance to it of another individual (the soon-to-be reactor), which fact makes one ponder whether the present case may be placed into a territorial defence scenario, that is to say the initiator felt compelled to defend its territory by an intruder. It has been debated whether *Octopus vulgaris* is a territorial cephalopod, however field studies have not evidenced any territoriality, but rather the fact that individuals of this species occupy home dens for days or weeks and then move to another place (Altman, 1967; Kayes, 1973; Mather & O'Dor, 1991); to sum up, Hanlon & Messenger (2018) state that territoriality is unproven for this octopus.

It is known that the 17th and 18th suckers on the lateral arms are markedly enlarged in mature males of *O. vulgaris* (Naef, 1923), which constitutes a sexual dimorphic character of the male. According to Packard (1961), the display of these large suckers may become a male-to-female recognition signal, especially important when the male is smaller than the female. In such a case, the proximal suckers are closed, by keeping folded on themselves, as to provide maximum contrast with the extra-large suckers. In other words, they function as a 'courtship display' (see also Borrelli et al., 2006). Wells & Wells (1972: 300) hypothesize that "sucker display is intended to identify the sex of an individual to other males." Yet, Hanlon & Messenger (2018) are sceptical about this matter. In the present case, it is indeed unlikely that both octopuses involved in the fight showed their large male suckers to prevent mating; possibly, both of them could not even see each other suckers because of their body posture. Most probably, the enlargement and display of the dimorphic suckers occurred at once with the extension and expansion of all suckers –

contrary to the courtship display where proximal suckers are closed – as part of the fighting patterns, oppose and retroflex in the initiator and the reactor, respectively.

It is noticeable that the initiator, when assaulting the supposed intruder, used one of the techniques in the *O. vulgaris* predatory repertoire, that is pouncing on the prey and enveloping it with its arm web (Hanlon & Messenger, 2018); indeed, just trying to envelop the opponent in the present case (Fig. 7). Of course, an octopus uses the best technique at its disposal to subdue an adversary, whether a prey or a conspecific reactor, which fact might indicate that 'pounce and envelop' is most probably the predatory technique reserved only or mostly for difficult prey items. Furthermore, in the present octopus fight, the initiator was uniformly dark coloured as during an attack on a prey.

In the described encounter and fight between two octopuses, it appears that in the first phase, the initiator's behaviour, conformed to the 'central programs,' among the few available, expressing the motor combinations appropriate to the fight situation: colour, body posture and moving, 'opposition' posture, webbing-over (Mather, 1998; Mather & Alupay, 2016). The output of the latter motor combination, namely webover, was hence modified to adapt it to the actual situation of body entanglement, where no visual information on grappling arms and webs was available, so that the initiator had to extensively adjust its arms locally (Mather, 1998).

Similarly, yet according to a defence program, the reactor at first adopted the 'retroflex' pattern, and, when webbed-over, tried to escape from under the initiator's arm web and succeeded in that. Again, at first the reactor conformed to 'central programs' and during the entanglement its arms acted independently by means of local adjustment. In short, both octopuses at first followed stereotyped 'central programs,' pre-constituted by evolutive processes, hence their arms acted by their own, at least to some extent (for further discussion on arm local control, cf. Mather, 1998).

Incidentally, the case discussed in this paper shows once more the importance of the visual channel in the confrontation between two adult male octopuses (cf. Hanlon & Messenger, 2018).

In the end, this intraspecific agonistic encounter between two similar-sized males caused no manifest severe injury to the loser, as it had seemingly been just a 'test of strength.' Octopus agonistic encounters were also described, among the others, by Scheel et al. (2016) in *Octopus tetricus* Gould, 1852, a littoral species slightly smaller than *O. vulgaris*. These authors maintain that non-cannibalistic octopus interactions indicate that their body pattern repertoires and behaviours may have evolved also in the context of signalling between conspecifics; which signalling is variable among species. In fact, the colour patterns displayed respectively by initiators and reactors (the former darker coloured than the latter) and their behaviours during male-male agonistic encounters are somewhat similar in both *O. tetricus* (Scheel et al., 2016) and *O. vulgaris* (present results).

Further descriptions of conspecific agonistic behaviour in *O. vulgaris*, rather scanty at present, are necessary to define its typical pattern and, in turn, compare it with that of other octopus species. In fact, other species may exhibit behaviours differing to a great extent; in this respect see, for instance, the male-male confrontations in *Abdopus aculeatus* (d'Orbigny, 1834), a small-sized octopus, generated by competition for female mates (Huffard, 2005, 2007). Behavioural similarities may indicate close phylogenetic relationships and vice versa. Hence well-defined ethograms may contribute towards drawing accurate phylogenetic trees for octopodids (Huffard, 2007).

Lastly, Hanlon & Messenger (2018) report that foraging octopuses, including *O. vulgaris*, are often followed by scavenging fishes. In the present case also, some fishes appeared to take advantage of an octopus activity, namely intraspecific fighting.

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Unravelling the complexity of *Corbicula* clams invasion in Italy (Bivalvia: Cyrenidae)

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Abstract

In the present paper the taxonomic status of several *Corbicula* populations, collected in different sites from northern and central Italy, is evaluated. At least four different species have been identified: *Corbicula fluminalis* (Müller, 1778), *Corbicula fluminea* (Müller, 1778), *Corbicula largillierti* (Philippi, 1844) and *Corbicula leana* Prime, 1867. The first two taxa were reported in Italy some decades ago; the second ones are known only since 2018 but, it is shown here that they were already present in the Italian territory, respectively since 2014 (*C. largillierti*) and 2002 (*C. leana*). Moreover, another taxon similar to *C. fluminea*, here called as *C. cf. fluminea*, is detected for the first time in Italy.

The identification of the different species was mainly carried out on the shell characters (general shape, number of ribs, appearance and position of the umbo, outer and inner colour of the valves); but for the most difficult taxa a morphometric analysis was also performed, by previously checking the range in which the growth follows a roughly isometric pattern. The morphometric analysis of *C. fluminea*, *C. cf. fluminea* and *C. leana* showed a wide variability of these characters, which do not always agree with diagnostic characters. However, some ratios are useful to distinguish these taxa, even if often only in their average values. Even the anatomical characters, in particular those related to the siphons, are quite variable and do not agree with other diagnostic characters. Such features would attest the presence of several distinct clones as, on the other hand, genetic investigations carried on specimens in other countries have confirmed.

C. fluminalis is not a very common species. It is only present in northern Italy, in some lake basins, especially in Lake Garda and, rarely, in its emissary, the Mincio River. *C. fluminea* is the most widespread species in northern Italy, in the Po River from Turin and mostly in its left tributaries, but also in the Veneto basins, in the east up to the Lemene basin, while it is less frequent in Tuscany and Latium. *C. cf. fluminea* is quite widespread but only in the central-western area of the Po basin. *C. largillierti* is present only in the lower Lake Garda, rarely in its emissary and it was also collected in the terminal stretch of the Po River. *C. leana* is fairly widespread in the north and it is the most represented species in Tuscany, in the Serchio and Arno basins.

However, the *Corbicula* clams occupy areas of the plain or at moderate altitudes, especially colonizing fine granulometry, sandy or muddy substrates, especially in lentic or lotic environments of potamal nature or in any case stable, such as artificial canals or irrigation networks. They are very tolerant to water pollution; however, they do not bear strong anoxia conditions, while they require waters with a good calcium hardness, moreover they react negatively to the aggressive conditions of the water, probably the main cause of umbonal corrosion that can lead to the formation of holes and death of the specimens.

Since the *Corbicula* species are very invasive, it is hoped that prevention interventions will be adopted, in order to avoid their spread in still free areas, even if the multiple human activities, that are the main potential causes of diffusion, and the present vast distribution throughout northern Italy, leave little hope for the future.

Key words

Corbicula, cryptic species, taxonomy, Italy, distribution.

Riassunto

Nel presente lavoro viene valutato lo stato tassonomico di numerose popolazioni di *Corbicula*, raccolte in diversi siti dell'Italia settentrionale e centrale. Sono state identificate almeno quattro specie differenti: *Corbicula fluminalis* (Müller, 1778), *Corbicula fluminea* (Müller, 1778), *Corbicula largillierti* (Philippi, 1844) e *Corbicula leana* Prime, 1867. I primi due taxa sono stati segnalati in Italia alcuni decenni fa; i secondi sono noti solo dal 2018 ma le nostre raccolte dimostrano che erano già presenti sul territorio italiano, rispettivamente dal 2014 (*C. largillierti*) e dal 2002 (*C. leana*). Inoltre, un altro taxon simile a *C. fluminea*, qui chiamato *C. cf. fluminea*, viene rilevato per la prima volta in Italia.

L'identificazione delle diverse specie è stata effettuata principalmente sui caratteri della conchiglia (forma generale, numero di coste, aspetto e posizione dell'umbone, colore esterno e interno delle valve); ma per i taxa più difficili da determinare è stata effettuata anche un'analisi morfometrica, controllando in precedenza l'intervallo in cui la crescita segue un andamento grossolanamente isometrico. L'analisi morfometrica di *C. fluminea*, *C. cf. fluminea* e *C. leana* ha mostrato un'ampia variabilità di questi caratteri, che non sempre concordano con i caratteri diagnostici. Tuttavia alcuni rapporti sono utili per distinguere questi taxa, anche se spesso solo nei loro valori medi. Anche i caratteri anatomici, in particolare quelli relativi ai

sifoni, sono abbastanza variabili e non concordano con altri caratteri diagnostici. Tali caratteristiche attesterebbero la presenza di più cloni distinti, come d'altra parte hanno confermato le indagini genetiche condotte su esemplari di altri Paesi.

C. fluminalis non è una specie molto comune. È presente solo nell'Italia settentrionale, in alcuni bacini lacustri, soprattutto nel Lago di Garda e, raramente, nel suo emissario, il Fiume Mincio. *C. fluminea* è la specie più diffusa nell'Italia settentrionale, nel Fiume Po a partire da Torino e soprattutto nei suoi affluenti di sinistra, ma anche nei bacini veneti, a est fino al bacino del Lemene, mentre è meno frequente in Toscana e nel Lazio. *C. cfr. fluminea* è abbastanza diffusa ma solo nell'area centro-occidentale del bacino del Po. *C. largillierii* è presente solo nel basso Lago di Garda, raramente nel suo emissario ed è stata raccolta anche nel tratto terminale del Po. *C. leana* è abbastanza diffusa al nord ed è la specie più rappresentata in Toscana, nei bacini del Serchio e dell'Arno.

Le *Corbicula* occupano zone di pianura o moderata altitudine, colonizzando principalmente substrati a granulometria fine, sabbiosi o fangosi, soprattutto in ambienti lentic o lotici di natura potamale o comunque stabili, come canali artificiali o reti irrigue. Sono molto tolleranti all'inquinamento delle acque; tuttavia, non sopportano condizioni di forte anossia, mentre richiedono acque con una buona durezza, inoltre reagiscono negativamente alle condizioni aggressive dell'acqua, probabilmente la principale causa di corrosione umbonale che può portare alla formazione di buchi e alla morte degli esemplari.

Essendo le specie di *Corbicula* molto invasive, si spera che vengano adottati interventi di prevenzione, per evitare la loro diffusione in aree ancora libere, anche se le molteplici attività umane, che sono le principali cause potenziali di diffusione e l'attuale vasta distribuzione in tutto il nord Italia, lasciano poche speranze per il futuro.

Parole chiave
Corbicula, specie criptiche, tassonomia, Italia, distribuzione.

Introduction

The genus *Corbicula* Megerle von Mühlfeld, 1811, includes many freshwater clam species, living in lotic and lentic environments, native of Asian, Oceanian and African regions. The taxonomy on species level is very difficult because no recent revisions, or only on restricted areas, have been published (Glaubrecht et al., 2003, 2007); the number of nominal species is very high: 462 recent and 127 fossil nominal species, of which type materials for 102 recent and 53 fossil taxa are missing or destroyed, according to Counts (1991). Therefore, the number of living valid species is very uncertain, according to different authors (e.g., about 12 by Prashad, 1928, and 14 by Subba Rao, 1989, from India; 34 by Prashad, 1929a, 1929b, from Asia, except India; about 17 by Jing & Zimin, 2013, from China; 6 by Glaubrecht et al.,

2003, from Indonesia; 3 by Van Damme, 1984, from Africa; overall 23 + 17).

Corbicula has been subject of a multitude of scientific articles, for example Counts (2006) reports over 2,500 references to the literature, due to their interest in taxonomy, biochemical, as pollution indicator, genetics, reproductive strategy, development and invasiveness. In fact, several taxa were introduced as alien species in America (first introduction on 1924 in the United States), in northern Africa (first introduction on 2008 in Morocco) and in Europe from 1976 (Counts, 1981; Mouthon, 1981; McMahon, 1982; Araujo et al., 1993; Ituarte, 1994; Eliot & Ermgassen, 2008; Clavero et al., 2012; Azevêdo et al., 2014; Pereira et al., 2014; Quiñonero-Salgado & López-Soriano, 2014, 2016a, 2016b; Hesse et al., 2015; Tiemann et al., 2017). So much that one, *Corbicula fluminea* (Müller, 1778), is considered among the 100

Table 1. Presence of *Corbicula* spp. in European countries, with the year of the first published paper. For acronyms of species see Material and methods. References: AT - FLU: Fischer & Schultz, 1999. BE - FLS, FLU: Swinnen et al., 1998. BG - FLU: Hubenov, 2001. HR - FLU: Lajtner, 2015. CZ - FLU: Beran, 2000. RU - FLU: Zhivoglyadova & Revkov, 2018. FR - FLU: Mouthon, 1981; FLS: Renard et al., 2000; LEA: Marescaux et al., 2010, as "*Corbicula* form R", according to Quiñonero-Salgado & López-Soriano, 2017b. DE - FLU: Bij de Vaate, 1991; Kinzelbach, 1991; FLS: Alf, 1992; Haesloop, 1992; LAR: Nesemann, 2018. GB - FLU: Baker et al., 1999; Howlett & Baker, 1999. GR - FLU: Karaouzas et al., 2020. HU - FLS, FLU: Csányi, 1999. IE - FLU: Sweeney, 2009. IT - FLU: Fabbri & Landi, 1999; Malavasi et al., 1999; FLS: Cianfanelli et al., 2007; LAR, LEA: López-Soriano et al., 2018. LU - FLS, FLU: Ries et al., 2017. MK - FLU: Zieritz, 2015. MD - FLU: Munjiu & Shubernetski, 2010. PL - FLU: Domagała et al., 2004; FLS: Łabęcka et al., 2005. PT - FLU: Mouthon, 1981 (see Holyoak et al., 2019; also the record by Nagel, 1989, maybe *C. fluminea*). RO - FLU: Bij de Vaate & Hulea, 2000. RS - FLS, FLU: Paunović et al., 2007. SK - FLU: Vrabec et al., 2003. SI - FLU: Bizjak Govedič & Govedič, 2018. ES - FLU: Pérez-Quintero, 1990; FLS: Quiñonero-Salgado & López-Soriano, 2014; INS, JAV, LAR, LEA, PRO: López-Soriano & Quiñonero-Salgado, 2016; Quiñonero-Salgado & López-Soriano, 2016a, 2016b. CH - FLS, FLU: Turner et al., 1998. NL - FLU: Bij de Vaate & Greijdanus-Klaas, 1990; FLS: Blanken, 1990. UA - FLS: Vashkevich & Son, 2002; FLU: Lyashenko et al., 2005.

Tab. 1. Presenza di *Corbicula* spp. nelle nazioni europee, con l'anno della prima pubblicazione. Per le sigle delle specie si veda Materiali e metodi. Riferimenti: AT - FLU: Fischer & Schultz, 1999. BE - FLS, FLU: Swinnen et al., 1998. BG - FLU: Hubenov, 2001. HR - FLU: Lajtner, 2015. CZ - FLU: Beran, 2000. RU - FLU: Zivoglyadova & Revkov, 2018. FR - FLU: Mouthon, 1981; FLS: Renard et al., 2000; LEA: Marescaux et al., 2010, come "*Corbicula* form R", secondo Quiñonero-Salgado & López-Soriano, 2017b. DE - FLU: Bij de Vaate, 1991; Kinzelbach, 1991; FLS: Alf, 1992; Haesloop, 1992; LAR: Nesemann, 2018. GB - FLU: Baker et al., 1999; Howlett & Baker, 1999. GR - FLU: Karaouzas et al., 2020. HU - FLS, FLU: Csányi, 1999. IE - FLU: Sweeney, 2009. IT - FLU: Fabbri & Landi, 1999; Malavasi et al., 1999; FLS: Cianfanelli et al., 2007; LAR, LEA: López-Soriano et al., 2018. LU - FLS, FLU: Ries et al., 2017. MK - FLU: Zieritz, 2015. MD - FLU: Munjiu & Shubernetski, 2010. PL - FLU: Domagała et al., 2004; FLS: Łabęcka et al., 2005. PT - FLU: Mouthon, 1981 (vedi Holyoak et al., 2019; anche la segnalazione di Nagel, 1989, potrebbe riferirsi a *C. fluminea*). RO - FLU: Bij de Vaate & Hulea, 2000. RS - FLS, FLU: Paunović et al., 2007. SK - FLU: Vrabec et al., 2003. SI - FLU: Bizjak Govedič & Govedič, 2018. ES - FLU: Pérez-Quintero, 1990; FLS: Quiñonero-Salgado & López-Soriano, 2014; INS, JAV, LAR, LEA, PRO: López-Soriano & Quiñonero-Salgado, 2016; Quiñonero-Salgado & López-Soriano, 2016a, 2016b. CH - FLS, FLU: Turner et al., 1998. NL - FLU: Bij de Vaate & Greijdanus-Klaas, 1990; FLS: Blanken, 1990. UA - FLS: Vashkevich & Son, 2002; FLU: Lyashenko et al., 2005.

worst invasive species in the world (Lowe et al., 2000), but also other species have a high invasive potential (Reyna et al., 2018). Until few years ago, in Europe, only two *Corbicula* species were recognized: *C. fluminea* (Müller, 1778), native from south-eastern Asia, and *C. fluminalis* (Müller, 1778), native from Near-Middle East. *C. fluminea* was introduced at least in twenty-five countries, *C. flumina-*

lis at least in thirteen (Gherardi et al., 2013; Cianfanelli et al., 2016; Bank, 2017; **Table 1**). Recently, other species were recorded in Spain and France; particularly, in the north east of the Iberian Peninsula, up to seven different taxa seem to be present, distinguished by peculiar morphological characters and no apparent intermediate nor hybrid forms seem to exist (Quiñonero-Salgado & López-Soriano, 2016a; 2016b). But it is very difficult to

		1	2	3	4	5	6	7	
	Country \ Species	<i>C. fluminalis</i> (Müller, 1774)	<i>C. fluminea</i> (Müller, 1774)	<i>C. cf. insularis</i> Prime, 1867	<i>C. cf. javanica</i> (Mousson, 1849)	<i>C. largillierti</i> (Philippi, 1844)	<i>C. leana</i> Prime, 1867	<i>C. cf. producta</i> Martens, 1905	Ref.
1	Albania								
2	Andorra								
3	Austria		1999						AT
4	Belarus								
5	Belgium	1998	1998						BE
6	Bosnia and Herzegovina								
7	Bulgaria		2001						BG
8	Croatia		2015						HR
9	Cyprus								
10	Czech Republic		2000						CZ
11	Denmark								
12	Estonia								
13	European Russia		2018						RU
14	European Turkey								
15	Finland								
16	France	2000	1981				2010		FR
17	Germany	1992	1991			2018			DE
18	Great Britain		1999						GB
19	Greece		2020						GR
20	Hungary	1999	1999						HU
21	Iceland								
22	Ireland		2009						IE
23	Italy	2007	1999			2018	2018		IT
24	Kosovo								
25	Latvia								
26	Liechtenstein								
27	Lithuania								
28	Luxembourg	2017	2017						LU
29	Macedonia		2015						MK
30	Malta								
31	Moldova		2010						MD
32	Montenegro								
33	Norway								
34	Poland	2005	2004						PL
35	Portugal		1981						PT
36	Romania		2000						RO
37	Serbia	2007	2007						RS
38	Slovak Republic		2003						SK
39	Slovenia		2018						SI
40	Spain	2014	1990	2016	2016	2016	2016	2016	ES
41	Sweden								
42	Switzerland	1998	1998						CH
43	The Netherlands	1990	1990						NL
44	Ukraine	2002	2005						UA
	N° countries with <i>Corbicula</i>	12	26	1	1	3	3	1	

ascertain, in this genus, the identity of the invasive populations, because many native species were described without a comparative morphological analysis and the identity of others is still uncertain. In many cases, also the genetic data do not allow to identify the specimens, because of their reproductive strategy, including clonal and androgenetic reproduction, recurring in invasive populations (Renard et al., 2000; Glaubrecht et al., 2003; Hedtke et al., 2008; Pigneur et al., 2011, 2012, 2014a; Tiemann et al., 2017; Haponski & Ó Foighil, 2019; Araujo et al., 2020).

The oldest data of *Corbicula* clam known from Italy is due by Mienis (1991), who mentioned a single complete specimen of *C. fluminea*, stored in the Coen collection at the Hebrew University of Jerusalem (Israel), collected before 1940 in Trapani, western Sicily. However, the Sicilian record has never been confirmed later. According to Marrone & Naselli-Flores (2015), it is possible that this old data is to ascribe to a mislabelling of a museum specimen; anyway, because the label was manuscript by Coen himself with a new species name, the mislabelling could be excluded (Mienis, 1991). Later, the first reliable records of this species from Italy are dated in 1998-1999, in the lower section of the Po River and in the surrounding inner waters of Emilia-Romagna, Lombardy and Veneto (Fabbri & Landi, 1999; Malavasi et al., 1999). In the early years of this century, *C. fluminea* was spread to several watercourses and springs in Lombardy (Pezzoli, 2009, 2010; Hallgass & Vannozzi, 2010; Genoni et al., 2008; Nardi, 2010; ARPA Lombardia, 2013), in the Lombardian and Venetian sides of Lake Garda (Nardi & Braccia, 2004), where it formed massive populations in a short time (Ciutti et al., 2007, 2009, 2011; Ciutti, & Cappelletti, 2009; Cappelletti & Ciutti, 2017). Other data on its Italian distribution were published by Bodon et al. (2005) and Cianfanelli et al. (2007); later, this taxon was also collected in the Venetian plain, in the Brenta and Bacchiglione basins (Niero & Bodon, 2011), in the Senio River and in the Emiliano-Romagnolo Canal, in Ravenna province, Emilia-Romagna (Pezzi, 2008; Stagoni, 2009) and in the Lake Maggiore, where consistent populations are known (Guarneri, 2013; Kamburska et al., 2013). In recent years the populations of the Pavia province were studied, in waters near the Ticino basin (Nicolini & Lodola, 2011; Rodolfi et al., 2017; Paganelli et al., 2018a, 2018b). In addition to the northern Italy data, where *C. fluminea* lives in the Padano-Venetian area, new data were recorded from Tuscany, where the species has been recorded in the Serchio River, Lucca province (Ercolini & Cenni, 2015) and from Latium, in Macerese area and in the Lake Albano (Grana & Di Giuseppe, 2020). But all these data related to *C. fluminea* have uncertain specific determination, due to the presence of some other similar cryptic species.

The second *Corbicula* species known from Italy, recorded since 2004, is *Corbicula fluminalis*. It has been found in a little Alpine lake in Trentino but, due to the ecological condition, it is difficult to be sure that this species lives there (Cianfanelli et al., 2007). Later, since 2008, *C. fluminalis* was collected in Lake Garda (Ciutti &

Cappelletti, 2009; Ciutti et al., 2011). Finally, a recent revision of the populations living in this lake, allowed to ascertain the presence of two more species in several stations in the southern area of this lake: *Corbicula largillierti* (Philippi, 1844), native from China and *Corbicula leana* Prime, 1867, native from Japan (López-Soriano et al., 2018).

In conclusion, in Italy, only two *Corbicula* species were known until 2017 (*C. fluminea* and *C. fluminalis*) and only since 2018 two more cryptic species were recorded (*C. largillierti* and *C. leana*). In any case, all papers suggest that the Italian invasive populations of *Corbicula* should be better studied in their diagnostic morphological characters, because they could include more than just four different species.

The aim of this work is to evaluate the composition of the invasive Italian populations of *Corbicula*, some recorded in the past and others recently collected by the authors, to confirm their taxonomic determination and to verify the spread of the genus and of every single species in Italy.

Materials and methods

From 1999 to 2019 the authors and their collaborators collected empty shells and living specimens of *Corbicula* species in gravely, sandy or muddy substrates of Italian rivers and lakes. When mud or fine debris were present, a fishing-net or a benthos-net were utilized to separate the clams from the sediment. In standardised assessment of the macroinvertebrate community, a Surber-net with mesh size 500 micron was used. Sometimes, a trawl dredge has been used to search specimens in deeper waters. In addition to the living material, other dead specimens (empty shells) of the same populations were also collected by hand from debris or alluvial substrate. Photographs of living specimens and dry shells were taken with a digital camera.

For morphological analyses, about 20 dextral valves of well-developed shells (at least 15 mm of height/length) from 16 different Italian populations were used. The following parameters, with 0.1 mm accuracy, have been measured for each shell (**Fig. 1**): H= maximum height; L= maximum length; Hu= height of umbo; Hh= height of hinge plate under umbo; La= anterior length (between anterior edge and umbo); Lp= posterior length (between posterior edge and umbo); α = angle between the centre of the hinge plate (below the umbo) and the end of cardinal teeth.

In each population, the relationships between the different parameters have been verified, checking if they vary significantly with the shell size (allometric growth) or if their trend is constant (isometric growth) in the dimensional range considered (height - length medium between about 15 and 30 mm). Once the type of growth has been defined, only the homogeneous classes were considered, and a statistical comparison among the different populations and the different species has been made, to verify the useful diagnostic parameters.

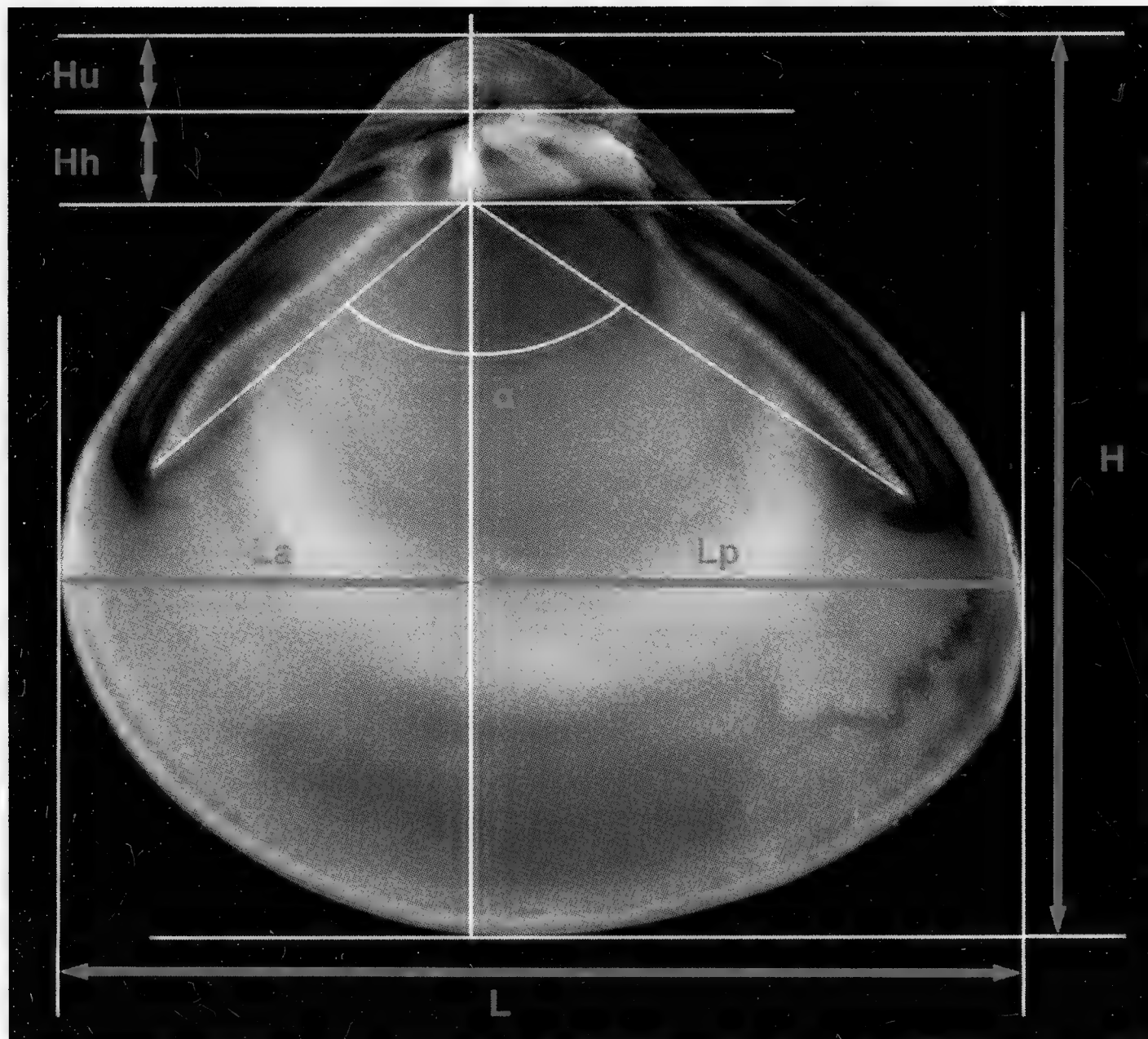


Fig. 1. Measured parameters on *Corbicula* shells. H= maximum height; L= maximum length; Hu= height of umbo; Hh= height of hinge plate under umbo; La= anterior length (between anterior edge and umbo); Lp= posterior length (between posterior edge and umbo); α = angle between the centre of the hinge plate (below the umbo) and the end of cardinal teeth.

Fig. 1. Parametri misurati sulle conchiglie di *Corbicula*. H= altezza massima; L= lunghezza massima; Hu= altezza dell'umbone; Hh= altezza della placca della cerniera sotto l'umbone; La= lunghezza anteriore (tra il bordo anteriore e l'umbone); Lp= lunghezza posteriore (tra il bordo posteriore e l'umbone); α = angolo tra il centro della placca della cerniera (sotto l'umbone) e il termine dei denti cardinali.

Then the significance level of the relationship between the different populations and the different species has been verified by means of univariate and multivariate analysis. Therefore, after observation of a non-normal distribution of the data and the non-homogeneous variances (with the application of the Shapiro Wilk and the Levene's test), in order to test the significance of the differences between the classes, the Kruskal-Wallis univariate non-parametric test and the Dunn's post hoc test were used. Moreover, the ANOSIM and PCA multivariate analysis for the analysis of similarities were performed. For these analyses the data have been normalized.

In this work the nMDS sorting technique (non-parametric multidimension scaling) was also used, which has the purpose of grouping together the objects (or variables), based on their similarity or correlation, so that the elements of a group are as similar as possible to each other. For this analysis, the data were normalized and the Bray-Curtis similarity coefficient was used. This coefficient, expressly recommended by many authors, is considered an excellent measure of similarity because it well preserves the "ecological distance" of the investigated communities (Clarke & Gorley, 2006). Statistical analysis was performed by Past 3.19, Hammer 1999-2018 software. Therefore, the better relationships describing the shape differences in the different *Corbicula* species have been sought. A database on Surber samplings of macroinvertebrate from ARPA Lombardia and ARPA Veneto in regional plain, on the years 2009-2018, has been utilised, and data for PCA processed by the same software. The same databases, with the ecological classification of the sites based on macroinvertebrates community, were utilized for verifying the pollution resistance of *Corbicula* clams and the trend of their spread in Lombardy. The data of pH, alkalinity and calcium hardness for the sites of ARPA Lombardia, processed through the AWWA (IA) index of

aggressivity, have been related to the level of umbonal corrosion of the shells.

For each shells or specimens collected and identified at species level, the collection data are listed in Appendix as follows, categorized in different Italian regions: water body and locality, altitude (meters above sea level, mostly with 5 m accuracy), municipality and province in parenthesis, UTM coordinates (ED50), collector(s) and collection date, taxon (FLS= *C. fluminalis*; FLU= *C. fluminea*; CLU= *C. cf. fluminea*; LAR= *C. largillierti*; LEA= *C. leana*), number of complete or single valves of dry shells (sh) and/or number of live collected specimens (sp), adult or young (juv), and abbreviations of the collections where they are stored in parentheses. For shells or specimens not determined at species level, the data are not reported but used in maps of the genus *Corbicula* only. Geographic names of the localities refer mostly to the official maps of Italy by Italian Military Geographic Institute, 1:25,000, 1:50,000 or 1:100,000; UTM coordinates were taken from the same sources or detected by GPS. Sites are reported, for each region, arranged by order of basin and sub-basin from north to south and from east to west, and from upstream to downstream.

The examined materials are preserved in the following collections: Museum of Natural History of Museum System of University of Florence, Zoological Section "La Specola" (Via Romana 17, Florence, Italy; MZUF); ARPA Lombardia (U.O. Centro Regionale Laghi e Monitoraggio Biologico Acque Superficiali, Settore Monitoraggi Ambientali, Via Einaudi 1, Como, Italy; ARPA-L); ARPA Veneto (DRL Servizio Analisi Biologiche Laboratorio Est sede di Treviso, Via Santa Barbara 5/A, Treviso, Italy and ARPA Veneto, DRL U.O. Analisi Biologiche Laboratorio Ovest sede di Vicenza, Via Zamenhof 353, Vicenza, Italy; ARPA-V); S. Birindelli (Via Caprera 37, Torino, Italy; SBC); M. Bodon (Via degli Iris 41/2, Genoa, Italy; MBC); A. Braccia (Via Ischia 19, Brescia,

Italy; ABC); S. Cianfanelli (Via Monferrato 3, Florence, Italy; SCC); G. Nardi (Via Boschette 8A, Gussago, Brescia, Italy; GNC); Joaquín López-Soriano (Museu Blau, Plaça Leonardo da Vinci 4-5, Barcelona, Spain; JLC); P. Ercolini (Via di Coli e Spezi 2653/b, Piano del Quercione, Lucca, Italy; PEC); I. Niero (Via Cici 17/1, Spinea, Venezia, Italy; INC); Sergio Quiñonero-Salgado (Associació Catalana de Malacologia-Museu Blau, Plaça Leonardo da Vinci 4-5, Barcelona, Spain, SQC).

Results

Morphometric analysis

The morphometric analysis was carried out on some populations of the most widespread species in Italian watercourses, more problematic to identify and on which an adequate number of shells were available (Table 2; species marked in heavy-type in Appendix). The considered species are the following: *Corbicula fluminea*, *Corbicula leana* and *Corbicula* cf. *fluminea*, a taxon not yet identified with certainty, similar to *C. fluminea*, but probably distinct from it. The three taxa were determined by their morphological characters (mainly based on the shell shape, the umbo, the internal colour of the valves and lateral teeth). Specimens between about 15-30 mm were measured because, in *C. fluminea*, these dimensions correspond to an age of about 1 to almost 3 years, that is the phase of sexual maturity (Mouthon & Parghentanian, 2004; Guarneri, 2013; Kamburska et al., 2013). Therefore, regarding these measurements, the young specimens and those of excessive size were excluded, to guarantee a better uniformity of data. In the measurements performed on the shell (Fig. 1), the ratios that best describe the differences observed among the single taxa were calculated: H/L maximum height / maximum length (shape of the shell); Hu/Hh height of umbo / height of hinge plate (development of the umbo compared to hinge plate); (Hu+Hh)/H height of umbo + hinge plate / maximum shell height (development of the umbo + hinge plate compared to shell height); Hu/H height of umbo / maximum shell height (development of the umbo compared to shell height); Hh/H height of hinge plate / maximum shell height (development of the hinge plate compared to shell height); La/Lp anterior length / posterior length (asymmetry of the shell); α , angle alpha between the centre of the hinge and the end of cardinal teeth (angular width of lateral teeth) (Table 2). Width of the valves was not measured because of its limited diagnostic value between these three taxa. Shell mass is another useful character to distinguish *C. fluminea* from *C. leana*, but the shell was not weighted because shell mass may be related with water hardness and some populations show corrosion on the shells which alters the original weight.

Analyzing the average values of the ratios in the different parameters of *C. fluminea* and *C. leana*, separated in three dimensional classes (≥ 15 , ≥ 20 , ≥ 25 mm), a certain difference related to the growth is evident, variable in

relation to the taxon and the considered parameter. The Kruskal-Wallis statistical test reveals a significant difference ($p < 0.05$ or $p < 0.01$) among the three dimensional classes, both in *C. fluminea* and in *C. leana*, for almost all ratios (Table 3). This difference is evident above all in the ≥ 25 class compared to the smaller ones, as noted by Dunn's post hoc test. Considering only the dimensional classes ≥ 15 and ≥ 25 , and also including *C. cf. fluminea* (which does not cover the size class ≥ 25 with a sufficient number of specimens), the Kruskal-Wallis test does not detect a significant difference between these two dimensional classes on most ratios, or, where the difference is significant, the significance threshold value is often at the limit of the significance (p value is slightly less than 0.05; Table 3). Therefore, in each taxon, in the 15-25 mm range, a variation of the ratios respect to the dimensions is not very evident. Moreover, because also the first two classes are both well represented in the three taxa, it is considered justified to elaborate the data by cumulating these two dimensional classes. On the other hand, at least for the H/L ratio, the growth model in the considered dimensional range (15-25 mm) appears isometric both in a population of *C. fluminea* of Lake Garda and in a population of *C. leana* of Serchio River (Ciutti & Cappelletti, 2009; Ercolini & Cenni, 2015, as *C. fluminea*).

The same applied statistical tests, for each taxon, to the first two dimensional classes of single populations, always show high significant differences among the different populations, for all ratios (p value < 0.01). Indeed the ranges, represented by the mean \pm standard deviation and minimum-maximum, show intervals sometimes different within the individual taxa (Fig. 2), while the considered parameters are almost always well correlated linearly, even considering all the dimensional classes (Fig. 3, level of significance, based on the values of R^2 , almost always $> 99\%$, with the exception of Hu/Hh for *C. cf. fluminea*, but this could depend by the greater umbonal corrosion in the larger specimens). The trend of the regression is well represented by a straight line, despite the allometric growth model described before that, in any case, it does not differ much from a linear trend. This confirms the choice to cumulatively elaborate the two dimensional classes.

On the other hand, analyzing the values of the different relations (H/L, Hu/Hh, (Hu+Hh)/H, Hu/H, Hh/H, La/Lp, α), measured on single specimens, through the ANOSIM, significant differences are found between the pairs of all three taxa, *C. fluminea*, *C. cf. fluminea* and *C. leana* (R : 0.4334; p value 0.0001). Even among the single populations in pairs the differences are almost always significant, not only between those of different species, but also those within the same species. Particularly within *C. leana* and *C. cf. fluminea* all populations are different. Even in *C. fluminea* many populations are different, those similar to each other are few, for example those of Lake Mergozzo, Lake Maggiore and Ticino River, water bodies belonging to the same sub-basin. Only one population attributed to *C. cf. fluminea*, collected in the "Naviglio Grande" (Milan), any-

Species Province Lake / River	H	Hu	Hh	L	La	Lp	H/L	Hu/Hh	(Hu+Hh)/H	Hu/H	Hh/H	La/Lp	α	N
FLU PV Ticino R.	19.7	1.6	1.8	21.4	9.8	11.6	0.923	0.921	0.177	0.084	0.093	0.855	108.5	20
	14.7-25.8	1.3-2.5	1.3-2.3	15.8-28.5	7.5-13.0	8.3-15.6	0.817-0.961	0.651-1.527	0.160-0.202	0.065-0.115	0.067-0.105	0.757-0.902	105.0-111.3	
	22.5	1.7	1.9	24.8	11.3	13.4	0.913	0.887	0.159	0.074	0.085	0.850	110.7	20
FLU VB L. Maggiore	14.7-25.8	1.1-2.3	1.5-2.7	17.0-32.3	8.0-14.2	9.0-18.7	0.864-0.956	0.655-1.343	0.127-0.186	0.059-0.096	0.069-0.107	0.725-0.985	106.8-114.9	
FLU VB L. Mergozzo	17.5	1.4	1.5	19.8	9.2	10.6	0.882	0.940	0.167	0.081	0.087	0.878	111.6	25
	14.6-21.4	0.9-2.3	1.0-2.0	16.3-24.2	7.5-11.9	8.5-13.7	0.825-0.972	0.658-1.378	0.116-0.189	0.054-0.105	0.062-0.113	0.738 -1.389	103.9-117.2	
FLU BI L. Viverone	17.6	1.3	1.3	20.1	8.9	11.2	0.876	1.008	0.152	0.076	0.076	0.795	112.8	18
	13.7-21.1	1.0-1.9	0.9-1.7	15.6-23.0	7.1-10.6	8.4-13.0	0.831-0.926	0.790-1.203	0.135-0.170	0.063-0.091	0.064-0.085	0.733-0.860	106.5-116.4	
FLU BS L. Iseo	19.3	1.8	1.7	20.4	9.2	11.2	0.948	1.086	0.182	0.094	0.088	0.831	108.6	20
	15.7-22.3	1.4-2.3	1.5-2.0	16.0-23.8	7.5-10.9	8.2-13.2	0.901-0.989	0.874-1.420	0.159-0.202	0.076-0.116	0.074 -0.097	0.732-0.946	105.1-112.3	
FLU BG Oglio R.	22.1	1.9	1.9	23.8	10.7	13.2	0.938	1.014	0.176	0.089	0.088	0.805	107.1	20
	17.2-28.1	1.4-2.4	1.4-2.3	18.0-34.5	8.2-14.7	9.8-19.8	0.813-1.006	0.780-1.286	0.130-0.208	0.063-0.106	0.063-0.108	0.662-0.948	102.4-115.8	
FLU BS Oglio R.	22.7	1.6	1.7	25.9	11.3	14.6	0.876	0.979	0.146	0.072	0.074	0.770	111.9	21
	16.9-28.1	1.2-2.9	1.3-2.1	18.8-31.7	8.6-14.8	10.1-17.2	0.819-0.905	0.787-1.330	0.127-0.158	0.062-0.90	0.065-0.082	0.630-0.879	107.7-115.8	
FLU LO Adda R.	21.7	2.1	2.1	23.3	10.6	12.7	0.932	1.044	0.194	0.099	0.096	0.842	111.5	20
	16.4-26.2	1.6-2.7	1.6-2.5	17.6-28.4	8.4-13.0	9.3-16.5	0.882-0.979	0.635-1.371	0.156-0.208	0.061-0.114	0.080-0.111	0.686-0.937	105.2-118.8	
FLU VE Sile R.	19.0	1.8	1.8	21.3	8.9	12.4	0.892	0.992	0.192	0.096	0.097	0.724	113.1	20
	14.5-23.7	1.3-2.5	1.4-2.3	15.9-27.5	6.7-10.8	9.2-16.8	0.863-0.927	0.763-1.183	0.168-0.212	0.073-0.115	0.086-0.105	0.623-0.835	111.0-115.3	
CLU MI Adda R.	17.9	1.0	1.5	20.2	9.5	10.7	0.882	0.619	0.140	0.054	0.087	0.892	112.6	17
	14.5-21.9	0.4-1.5	1.2-1.9	16.4-24.0	7.7-11.6	8.6-13.3	0.846-0.912	0.380-0.858	0.111-0.165	0.030-0.076	0.077-0.096	0.766-0.990	109.1-117.2	
CLU BG Oglio R.	18.5	1.2	1.6	21.1	9.2	12.0	0.877	0.781	0.150	0.066	0.085	0.770	110.6	11
	16.3-19.9	1.0-2.5	1.4-1.8	18.2-22.5	7.9-9.9	9.8-13.1	0.838-0.907	0.634-0.928	0.137-0.160	0.058-0.076	0.074-0.095	0.713-0.859	108.8-114.0	
CLU BG Sale D.	21.2	1.3	1.8	24.0	10.9	13.1	0.881	0.738	0.145	0.061	0.084	0.837	113.2	20
	15.7-25.7	1.0-1.8	1.2-2.2	18.4-28.0	8.9-13.2	9.5-15.6	0.805-0.945	0.590-0.927	0.132-0.160	0.052-0.071	0.069-0.091	0.738-0.942	106.2-119.6	
CLU MI Marinone C.	20.8	1.1	2.1	22.0	10.4	11.6	0.945	0.558	0.154	0.055	0.099	0.898	106.7	20
	18.4-25.1	0.8-1.6	1.6-2.8	19.9-26.9	8.6-12.6	9.7-14.3	0.987-1.064	0.408-0.822	0.126-0.175	0.038-0.078	0.085-0.110	0.765-1.086	100.4-111.3	
CLU MI Nav. Grande C.	17.4	1.3	1.6	19.5	9.5	10.1	0.887	0.833	0.167	0.075	0.092	0.942	113.9	20
	14.0-25.1	0.9-2.2	1.2-2.3	16.3-26.3	7.7-13.5	8.2-13.0	0.849-0.955	0.476-1.149	0.143-0.194	0.054-0.099	0.068-0.114	0.768-1.099	104.3-118.0	
LEA PV Ticino R.	19.6	1.5	1.6	22.8	10.6	12.2	0.861	0.956	0.158	0.076	0.082	0.872	118.9	21
	14.3-24.5	0.9-2.4	1.0-2.1	17.1-27.6	7.8-13.0	9.3-15.4	0.818-0.900	0.546-1.368	0.142-0.187	0.050-0.096	0.065-0.111	0.753-1.091	114.2-125.0	
LEA PD Storto B.	22.5	2.0	1.5	26.0	12.1	13.8	0.863	1.361	0.156	0.090	0.066	0.885	117.8	24
	14.5-30.4	1.2-2.9	0.8-2.3	17.4-35.4	8.0-17.5	9.4-19.3	0.808-918	1.039-1.754	0.134-0.172	0.073-0.103	0.056-0.076	0.728-1.073	110-123.5	
LEA LU Serchio C.	18.2	1.4	1.3	22.4	9.8	12.7	0.810	1.067	0.149	0.076	0.073	0.778	126.6	20
	13.6-24.1	0.8-2.2	0.8-1.7	16.8-28.9	7.7-12.4	9.1-16.6	0.777-0.833	0.644-1.586	0.133-0.165	0.052-0.098	0.060-0.088	0.642-0.900	124.0-129.2	
LEA PI S. Giuliano Terme D.	18.9	1.4	1.3	22.8	10.3	12.5	0.828	1.056	0.145	0.074	0.071	0.831	120.7	20
	14.5-21.9	1.0-2.0	1.1-2.9	18.7-29.0	8.8-13.3	9.8-17.0	0.810-0.844	0.798-1.278	0.132-0.153	0.060-0.087	0.058-0.080	0.701-0.949	116.2-126.2	

Table 2. Parameters measured on the shells and ratios between the parameters for each population of *Corbicula fluminea*, C. cf. *fluminea* and *C. leana*. Mean value and, below, min/max values; N: number of shells.

Tab. 2. Parametri misurati sulle conchiglie e rapporti tra i parametri per ogni popolazione di *Corbicula fluminea*, C. cfr. *fluminea* e *C. leana*. Valore medio e, sotto, valori min/max; N: numero di conchiglie.

Parameter	Classes: ≥15, ≥20, ≥25 mm		Classes: ≥15, ≥20 mm		
	<i>C. fluminea</i>	<i>C. leana</i>	<i>C. fluminea</i> *	<i>C. cf. fluminea</i> *	<i>C. leana</i> *
H/L	p<0.05 (15+ = 20+ ≠ 25+)	p<0.01 (15+ ≠ 20+ ≠ 25+)	p>0.05 (15+ = 20+)	p<0.05 (15+ ≠ 20+)	p<0.05 (15+ ≠ 20+)
Hu/Hh	p<0.05 (15+ = 20+ ≠ 25+)	p<0.01 (15+ = 20+ ≠ 25+)	p>0.05 (15+ = 20+)	p>0.05 (15+ = 20+)	p>0.05 (15+ = 20+)
(Hu+Hh)/H	p<0.01 (15+ = 20+ ≠ 25+)	p<0.01 (15+ ≠ 20+ ≠ 25+)	p>0.05 (15+ = 20+)	p>0.05 (15+ = 20+)	p<0.05 (15+ ≠ 20+)
Hu/H	p<0.01 (15+ = 20+ ≠ 25+)	p<0.01 (15+ ≠ 20+ ≠ 25+)	p>0.05 (15+ = 20+)	p>0.05 (15+ = 20+)	p<0.05 (15+ ≠ 20+)
Hh/H	p<0.01 (15+ = 20+ ≠ 25+)	p>0.05 (15+ = 20+ = 25+)	p>0.05 (15+ = 20+)	p>0.05 (15+ = 20+)	p>0.05 (15+ = 20+)
La/Lp	p<0.01 (15+ ≠ 20+ = 25+)	p>0.05 (15+ = 20+ = 25+)	p<0.01 (15+ ≠ 20+)	p>0.05 (15+ = 20+)	p>0.05 (15+ = 20+)
Alpha	p>0.05 (15+ = 20+ = 25+)	p<0.01 (15+ = 20+ ≠ 25+)	p>0.05 (15+ = 20+)	p<0.01 (15+ ≠ 20+)	p>0.05 (15+ = 20+)

Table 3. Statistical tests (Kruskal-Wallis test for medians and Dunn's post hoc for differences between the three classes) on the ratios of parameters measured on shells of *Corbicula* spp. from the populations listed in Table 1, divided in three dimensional classes (≥15 mm, ≥20 mm, ≥25 mm) on the basis of median value between height and length of shell (H+L)/2. p<0.01 highly significant; p<0.05 significant; p>0.05 not significant.

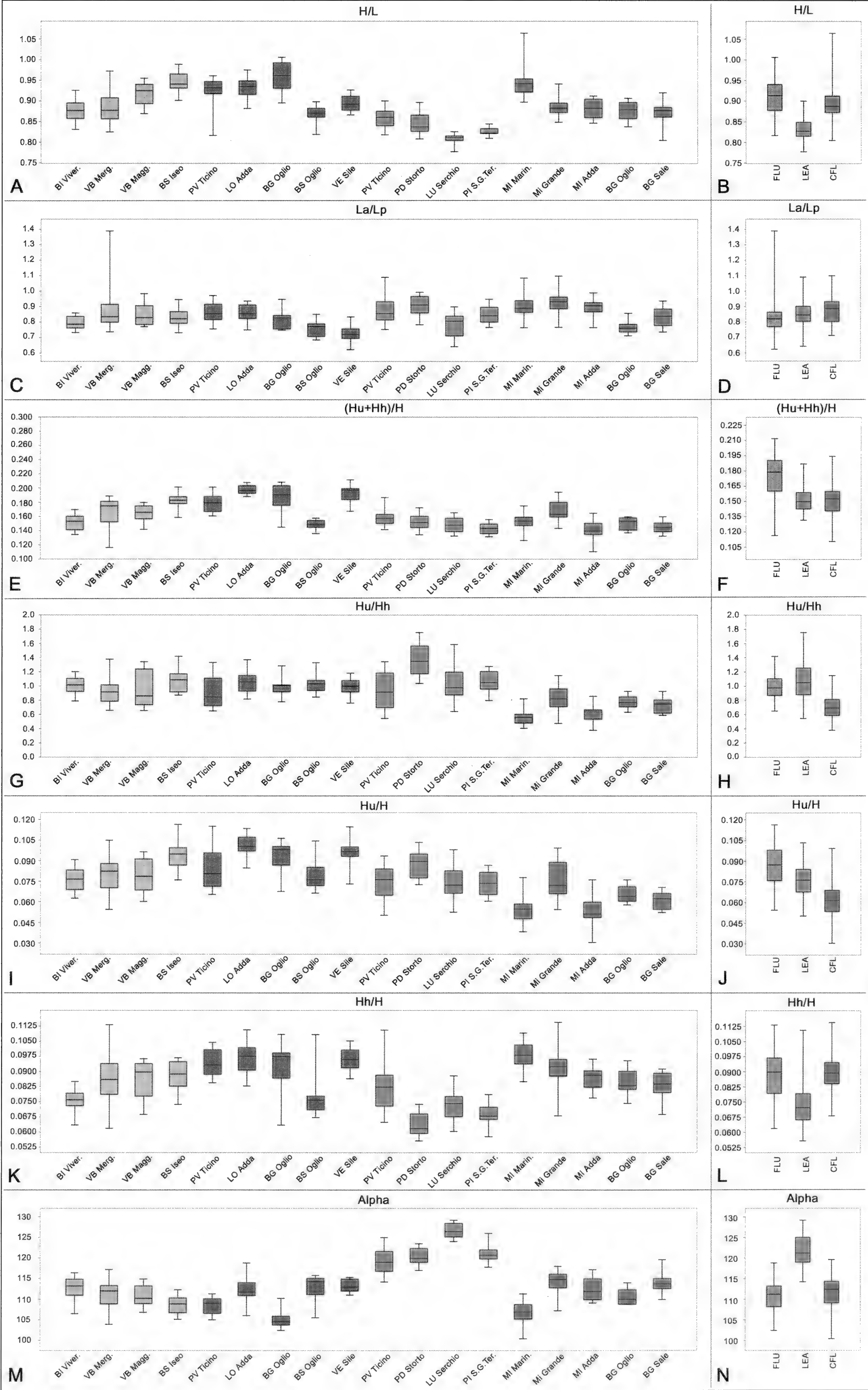
Tab. 3. Test statistici (test di Kruskal-Wallis per le mediane e post hoc di Dunn per le differenze tra le tre classi) sui rapporti dei parametri misurati su conchiglie di *Corbicula* spp. delle popolazioni elencate nella Tab. 1, suddivise in tre classi dimensionali (≥15 mm, ≥20 mm, ≥25 mm) sulla base del valore medio tra altezza e lunghezza della conchiglia (H+L)/2. p<0,01 valore altamente significativo; p<0,05 significativo; p>0,05 non significativo.

way powered by the same waters of the Ticino River, does not show significant differences with the other ones. However, among lake and river populations of *C. fluminea*, it does not seem that particular differences in morphometric parameters are present. Analyzing the same values of the relationships among the parameters, in the single specimens, through the Principal Coordinates Analysis (PCA), we obtain a percentage of variance of 60.7% on the first axis, 26.0% on the second, 9.3% on the third and 3.3% on the fourth. The relative graphic (Fig. 4. A) shows a wide dispersion of the points, without any well-defined grouping. However, *C. fluminea* extends mainly on the right and upper part of the graphic; *C. leana* is located mainly in the right and lower part, while *C. cf. fluminea* in the left side. The parameters conditioning this distribution are: in *C. fluminea* the greater size of the umbo or umbo + plate with respect to the height of the shell (ratio Hu/H or (Hu+Hh)/H higher); in *C. leana* the smaller size of the plate with respect to the umbo (higher Hu/Hh ratio); in *C. cf. fluminea* the smaller size of the umbo with respect to the plate (lower Hu/Hh ratio) or with respect to the height of the shell (lower Hu/H ratio). Strangely, the relationship between height and length of the shell (H/L) and the alpha angle, discriminating parameters between *C. fluminea* and *C. leana*, in this elaboration they have a negligible role (they are relevant only from the 4th axis, which has a negligible variance). Even the parameters relating to the anterior or posterior length of the shell (La/Lp, La/H or Lp/H), which are not very diagnostic, also play a negligible role. In addition, in the PCA, eliminating the parameters that may appear a little redundant (La/H, Lp/h, Hu/H and Hh/h) and thus highlighting the importance of the two discrim-

inating parameters between *C. fluminea* and *C. leana* (H/L and alpha) the result does not change. Through the Non-metric multidimensional Scaling analysis (nMDS) the results are similar (Fig. 4. C), but the lentic populations of *C. fluminea* (arranged along the negative values of the coordinate 1, but close to the zero of the coordinate 2) are better identified, if compared to those of lotic populations (arranged along the negative values of the coordinates 1, but more negative than the coordinates 2); moreover, *C. cf. fluminea* appears much more concentrated (and placed on positive values of the coordinate 1). Analyzing the average value of the parameters for each population through the Principal Coordinates Analysis (PCA), the results are similar, but the relationships among the single populations are more clearly identified (Fig. 4. B). The percentage of the variance obtained is 58.3% on the first axis, 33.0% on the second, 6.0% on the third and 2.4% on the fourth. Even in this case, the vectors are arranged in the same way and assume a similar importance; even in this case it is clearly evidenced the sensitive diversity among the different populations within the same taxon. A strong inhomogeneity occurs especially for the different populations of *C. fluminea*; however, the strong variability in *C. fluminea* populations could also be related to the greater number of specimens and populations taken into consideration. The population of *C. leana* living in the Ticino River, in Northern Italy, appears very different from those of Tuscany and closer to those of *C. fluminea*, while the population of *C. leana* of Padua, in Veneto, is well diversified. Even the populations of *C. cf. fluminea* are quite heterogeneous. The analysis through nMDS confirms what observed by the PCA (Fig. 4. C).

Fig. 2. Box Plot of the main parameters measured on *Corbicula* shells for the dimensional classes of 15-20 mm and 20-25 mm, on the average (H+L)/2. Values of single populations (left) and grouped for each taxon (right). **A, B.** ratio H/L; **C, D.** ratio La/Lp; **E, F.** ratio (Hu+Hh)/H; **G, H.** ratio Hu/Hh; **I, J.** ratio Hu/H; **K, L.** ratio Hh/H; **M, N:** angle alpha. Blue: *C. fluminea* (light blue: lentic populations; dark blue: lotic populations); yellow: *C. leana*; red: *C. cf. fluminea*.

Fig. 2. Box Plot dei principali parametri misurati sulle conchiglie di *Corbicula* per le classi dimensionali di 15-20 mm e 20-25 mm, in media come (H+L)/2. Valori delle singole popolazioni (a sinistra) e raggruppati per ogni taxon (a destra). **A, B.** rapporto H/L; **C, D.** rapporto La/Lp; **E, F.** rapporto (Hu+Hh)/H; **G, H.** rapporto Hu/Hh; **I, J.** rapporto Hu/H; **K, L.** rapporto Hh/H; **M, N:** angolo alfa. Blu: *C. fluminea* (azzurro chiaro: popolazioni lentiche; blu scuro: popolazioni lotiche); giallo: *C. leana*; rosso: *C. cf. fluminea*.



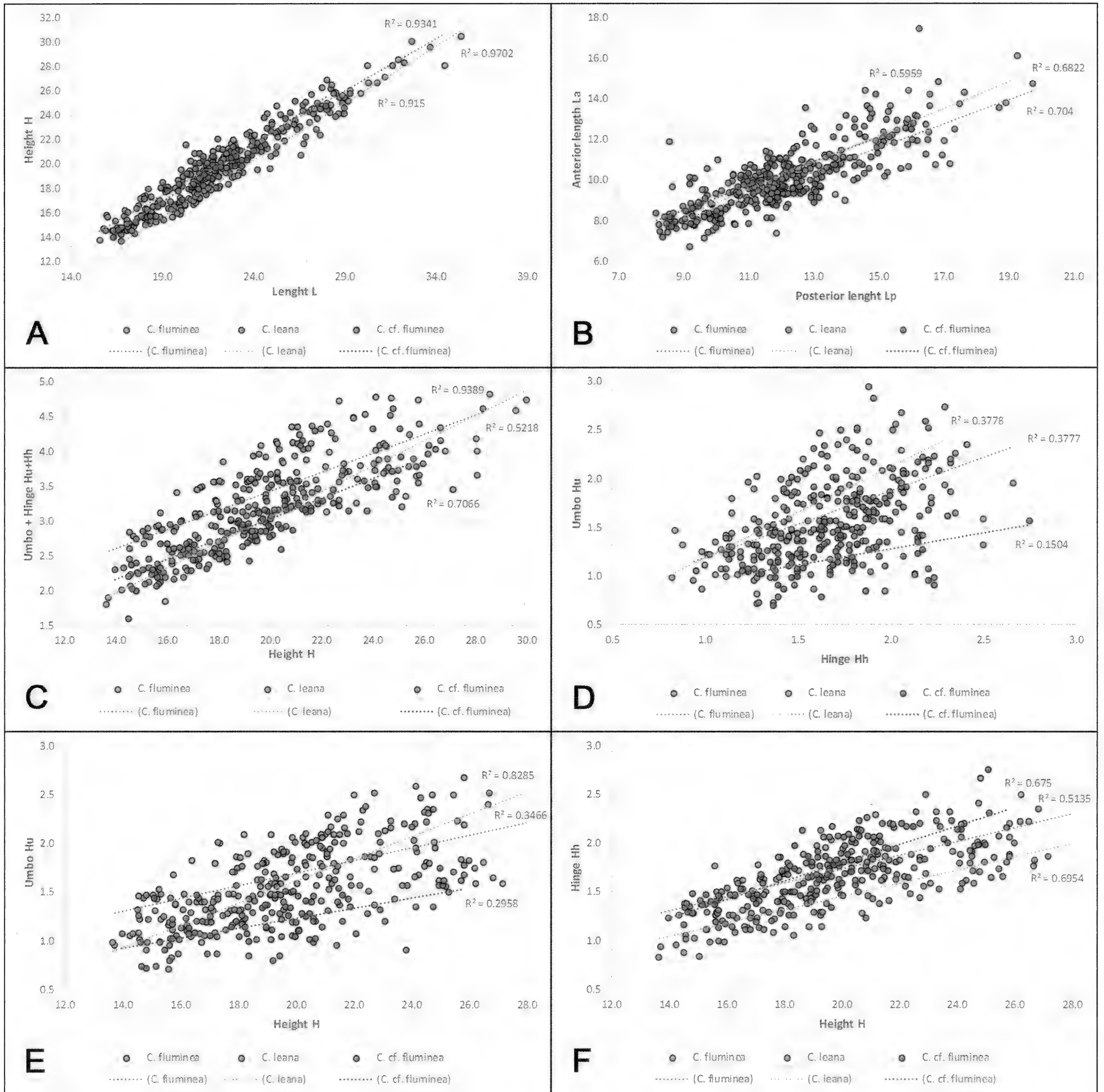


Fig. 3. Scatterplot of the values of the parameters on all specimens in the measured populations and trend of their ratios based on the linear curve. The best trend is represented, in many cases, not by a straight line (power, exponential or polynomial curve), but this approaches a linear trend for a weak allometry, more accentuated only for larger specimens. The correlation level is highly significant ($p \geq 99\%$), based on R^2 values, in all cases.

Fig. 3. Scatterplot dei valori dei parametri su tutti gli esemplari delle popolazioni misurate e andamento dei loro rapporti sulla base della curva della regressione lineare. La linea di tendenza migliore è rappresentata, in molti casi, non da una linea retta ma da una curva (potenza, esponenziale o polinomiale), ma l'andamento si avvicina ad una retta per una allometria debole, più accentuata solo per gli esemplari più grandi. Il livello di correlazione è altamente significativo ($p \geq 99\%$), in base ai valori di R^2 , in tutti i casi.

Finally, the UPMA Clustering Analysis on the average of the reports, shows how the single populations do not dispose according to the three identified taxa but, at least in some cases, they group the populations on the bases of the smaller geographical distance, like the population of *C. leana* from Ticino River, closer to those of *C. fluminea* of the same river, or the lakes of the same basin, than the populations of *C. leana* from Tuscany (**Fig. 4. D**). All this data show that the ratios used for the analysis are not very indicative to recognize the different species or, at least, there are many individuals or populations that present intermediate characters, which probably represent different clones, such as morphological and

genetic investigations on American and European populations have already highlighted (Renard et al., 2000; Pfenninger et al., 2002; Lee et al., 2005; Sousa et al., 2007; Hedtke et al., 2008; Pigneur et al., 2011, 2014a; Gomes et al., 2016; Peñarrubia et al., 2017; Tiemann et al., 2017; Haponski & Ó Foighil, 2019; Schrader & Brunken, 2019). In summary, the results show a wide variability in the values of the parameters considered in the individual populations and within each species; almost all reports can be considered discriminating for the three taxa considered, but only in their average values, with the exception of La/Lp , however having little significance. The main discriminating morphometric pa-

rameters, in specimens between 15-25 mm, in average \pm standard deviation, are (Fig. 5):

- H/L: higher in *C. fluminea* (0.91 ± 0.04), slightly lower in *C. cf. fluminea* (0.89 ± 0.04), lower in *C. leana* (0.83 ± 0.03) (shape of the shell highest in *C. fluminea* and in *C. cf. fluminea*, more elongated in *C. leana*);
- Hu/Hh: high in *C. fluminea* (0.99 ± 0.17), higher in *C. leana* (1.08 ± 0.26), although in the latter it is very variable, lower in *C. cf. fluminea* (0.70 ± 0.16) (umbo almost equal to the hinge plate in *C. fluminea* and in *C. leana*; narrower than the hinge plate in *C. cf. fluminea*);
- (Hu+Hh)/H: higher in *C. fluminea* (0.17 ± 0.02), lower in *C. leana* and in *C. cf. fluminea* (0.15 ± 0.01) (umbo + hinge plate higher in *C. fluminea*);
- Hu/H: higher in *C. fluminea* (0.087 ± 0.017), lower in *C. leana* (0.077 ± 0.011) and even lower in *C. cf. fluminea* (0.062 ± 0.013) (umbo higher in *C. fluminea*, intermediate in *C. leana* and lower in *C. cf. fluminea*);
- Hh/H: higher in *C. fluminea* (0.089 ± 0.011) and in *C. cf. fluminea* (0.090 ± 0.009), lower in *C. leana* (0.073 ± 0.010) (hinge plate lower in *C. leana*);
- La/H: lower in *C. fluminea* (0.089 ± 0.011), intermediate in *C. cf. fluminea* (0.090 ± 0.009), higher in *C. leana* (0.073 ± 0.010) (anterior length lower in *C. fluminea*, intermediate in *C. cf. fluminea* and higher in *C. leana*);
- Angle α : lower in *C. fluminea* (110.7 ± 3.5) and in *C. cf. fluminea* (111.7 ± 4.0), higher in *C. leana* (121.9 ± 3.8) (angle between the hinge edge and the end of the cardinal teeth narrower in *C. fluminea* and in *C. cf. fluminea*, wider in *C. leana*).

With respect to what is already published in the literature, even if an accurate comparison is not possible, due to the different dimensional classes considered, for the H/L ratio our results for *C. fluminea* are intermediate between data from Lake Garda in Italy (0.95) and from Ebro/Ter Rivers in Spain (0.87); also for *C. leana* our results are intermediate between data from Lake Garda in Italy (0.88) and from Ebro/Ter Rivers in Spain (0.80) (Quiñonero-Salgado & López-Soriano, 2016a, 2016b; López-Soriano et al., 2018).

Concerning the other species, a morphometric analysis comparing shell length and shell weight, has been employed by Quiñonero-Salgado & López-Soriano (2016a) from Ebro and Ter rivers populations, and by López-Soriano et al. (2018) from Lake Garda populations, to distinguish the *Corbicula* taxa, and reveals the morphological diagnostic characters to separate these species. *C. fluminalis* has by far the heaviest shell, and also has a ratio height/width much higher compared to the other species. *C. leana* and *C. largillierti* have similar proportions, but on average are much lighter than *C. fluminea*, which is placed in an intermediate position. Even the ratio height/length seems to allow differentiating some of these taxa, as this value (taken as the population mean) greatly differs among the analyzed taxa and seems relatively constant for each taxon: *C. fluminalis* is well over 1.0, *C. fluminea* and *C. largillierti* stand in intermediate position, and *C. leana* shows a relatively wider shell in comparison with all the other species (values <0.9), as

already described (Quiñonero-Salgado & López-Soriano, 2016a, 2016b).

These analyses, added to the clear morphological characters, despite some individuals of the different species may overlap in the cloud of points, help to distinguish the single taxa with little effort and minimal expertise, provided that fresh collected shells are studied.

Other diagnostic morphological characters (Figs 6-8; Table 4, key in Table 5)

The identification of the different *Corbicula* species, based on the shell morphology, is not often easy; it is very important to have very fresh specimens because, after the death of the animal, the inner surface of the valves loses the original color and becomes opaque quickly. Moreover, well-developed specimens are required (subadult or adult), although some diagnostic characters are more easily visible in young specimens, especially the coloured bands present on the umbo.

The shell shape and the outer colouring are both quite variable characters in the different populations and they can be influenced by genetic pools and many environmental factors (Prezant & Chalermwat, 1984b).

Corbicula fluminalis (Müller, 1778) (Fig. 6. A-D)

This species is easily recognizable for its stout shell, the triangular shape, higher than (or as long as) wide (height always shorter than length in other species), very swollen, with dense ribs on external surface (about 17-25/cm at centre of each valve), a very prominent umbo and a dark violet coloration of the inner surface of the valves (López-Soriano et al., 2018). The young shells show a dark colour on the inner surface of the valves but lack an evident band radiating from the umbo (Fig. 9. A-C).

Corbicula fluminea (Müller, 1778) (Fig. 7. A-R)

This species, very variable, is characterized by its asymmetrical shell, a prominent umbo, spaced ribs on external surface (about 8-11/cm at centre of each valve, up to 15 in Lake Garda specimens), whitish or pale violet coloration of the inner surface of the valves and little violet spots at the end of lateral teeth (Quiñonero-Salgado & López-Soriano, 2016a, 2016b; López-Soriano et al., 2018). The young shells show a narrow violet band radiating from the umbo (Fig. 9. F-K). It is difficult to distinguish *C. fluminea* from *C. leana* when using not fresh shells (faded inner surfaces of the valves) and, especially, from *C. cf. fluminea*. By a morphometric point of view, moreover it is distinct by the ratio H/L higher respect to that of *C. leana*, by the angle alpha lower than in *C. leana*, and by the ratio Hu/h lower than in *C. cf. fluminea*.

The largest dimensions measured are: H 38 mm, L 40 mm (Po River near Cremona).

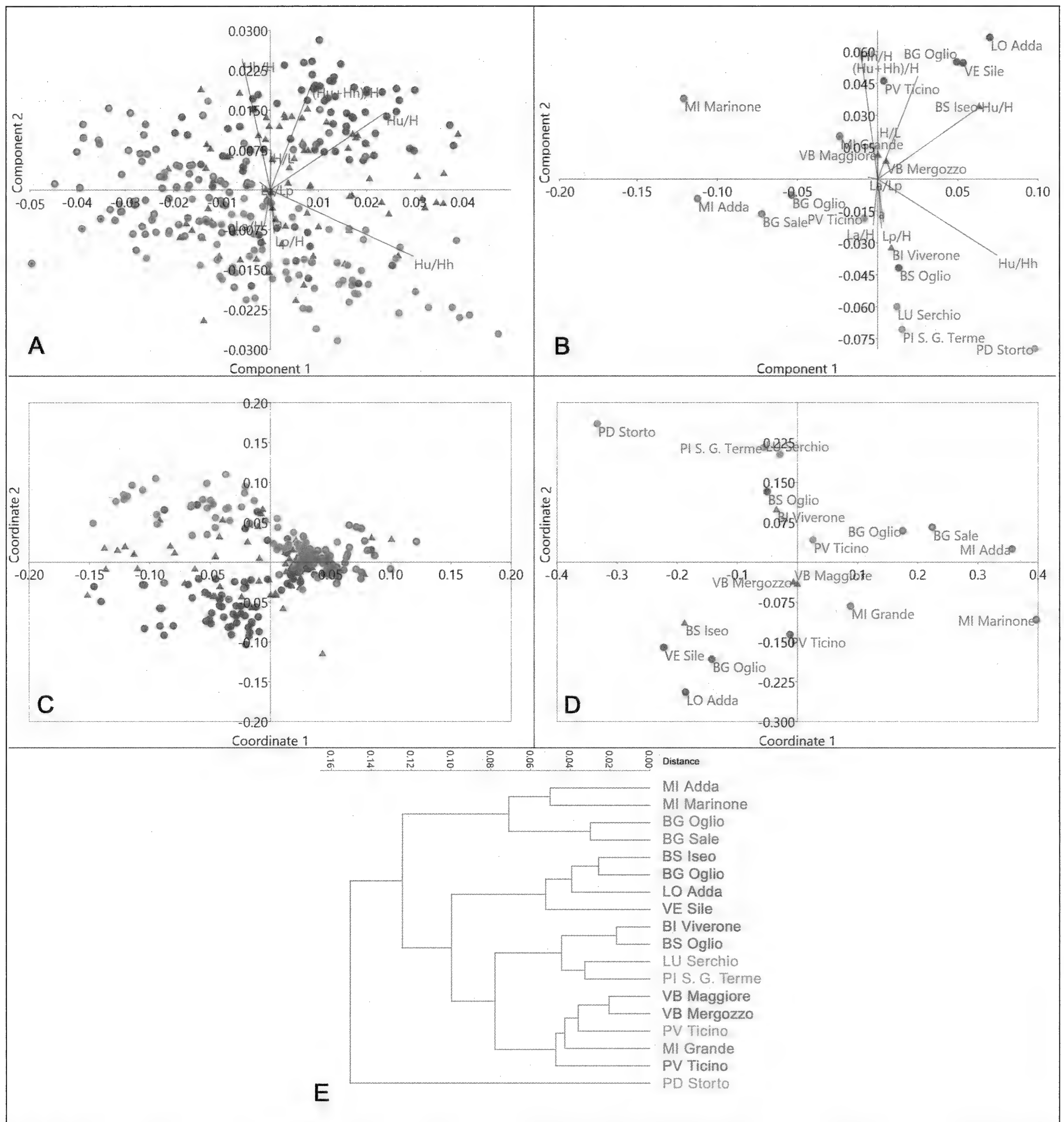


Fig. 4. **A, B.** Scatterplot of the two first components obtained from the Principal Component Analysis (PCA), and loadings of the main measured parameters, on specimens in the measured populations (**A**) or grouped for taxa (**B**); **C, D.** Non-metric multidimensional Scaling (nMDS) showing the similarity between the main measured parameters of the shells on specimens in the measured populations (**C**) or grouped for taxa (**D**); **E.** Cluster analysis with paired group (UPGMA) method showing the relationship between the main measured parameters of the shells grouped for taxa. Measured specimens only on 15-25 mm in dimensions. Symbols: blue dot: *C. fluminea*, lotic habitats; blue triangle: *C. fluminea*, lentic habitats; yellow dot: *C. leana*; red dot: *C. cf. fluminea*.

Fig. 4. Scatterplot dei primi due componenti ottenuti dall'Analisi delle Componenti Principali (PCA), e peso dei principali parametri misurati sui singoli esemplari delle popolazioni misurate (**A**) o raggruppati per popolazione (**B**); **C, D.** Multidimensional Scaling non metrico (nMDS) che mostra la similitudine in base ai principali parametri misurati su singoli esemplari delle popolazioni misurate (**C**) o raggruppati per popolazione (**D**); **E.** Cluster Analysis per gruppi accoppiati (UPGMA) metodo che mostra la relazione tra le popolazioni in base ai parametri misurati delle conchiglie. Sono stati misurati e analizzati solo gli esemplari di dimensioni tra 15 e 25 mm. Simboli: punto blu: *C. fluminea*, habitat lotici; triangolo blu: *C. fluminea*, habitat lentic; punto giallo: *C. leana*; punto rosso: *C. cf. fluminea*.

Corbicula cf. fluminea (Fig. 8. A-H)

This taxon is very similar to *C. fluminea*, but its shape is a little larger, equilateral, and its umbo is small and not prominent. The ribs are spaced (about 9-13/cm at centre of each valve) and the external coloration is

evenly dark brown, while the inner surface of the valves is whitish or pale violet; the lateral teeth are whitish with a large violet spot on their distal end. The young shells show a violet band radiating from the umbo, larger than in *C. fluminea* (Fig. 9 L-O). By a morphometric point of view, the ratio H/L is intermediate respect to that of *C. fluminea* and *C. leana*; Hu/Hh is lower

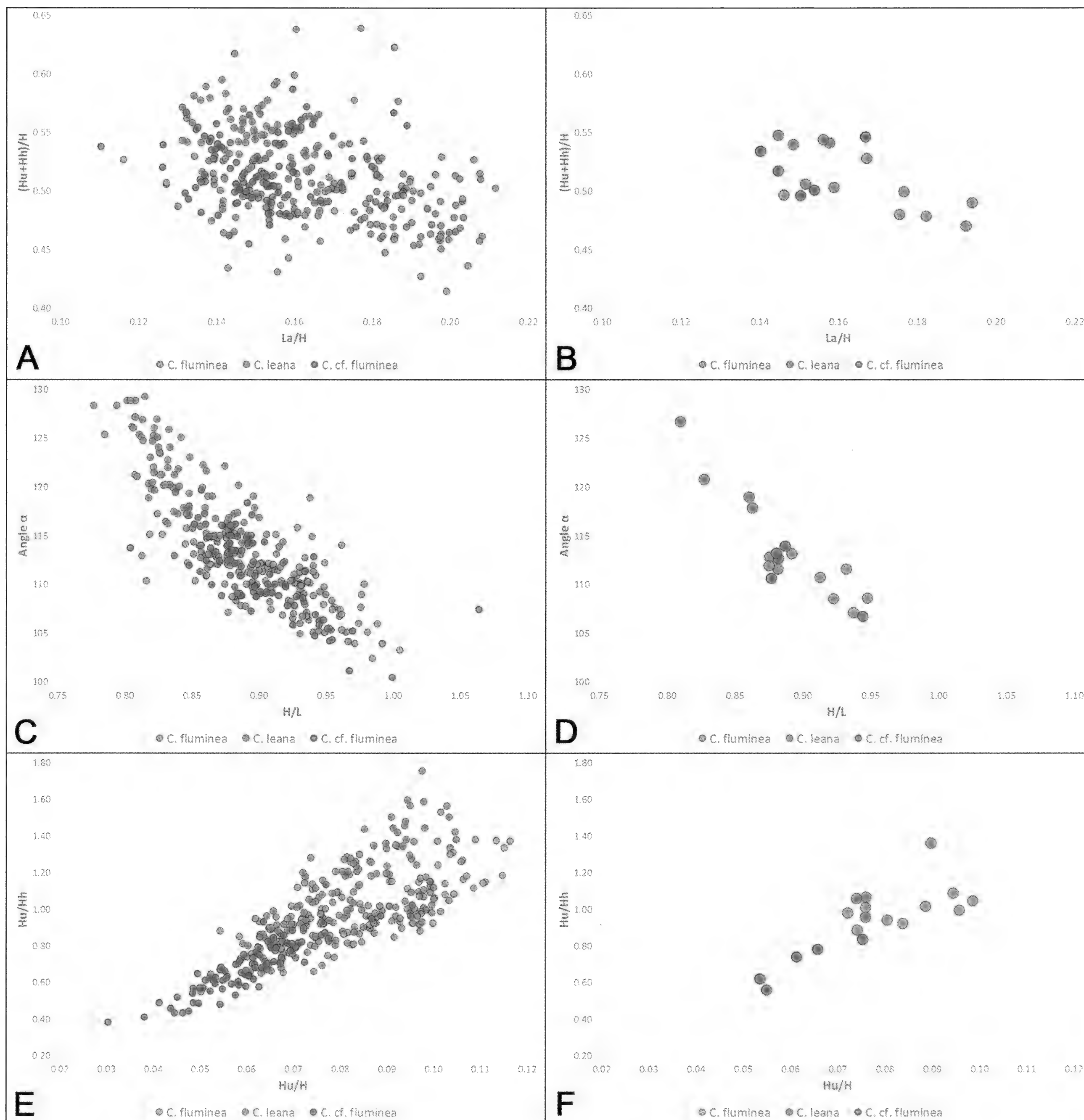


Fig. 5. Scatterplot of the ratio of the main parameters useful to distinguish *C. fluminea* (A, B), *C. leana* (C, D) and *C. cf. fluminea* (E, F), on all specimens in the measured populations (A, C, E) or in average for populations (B, D, F).

Fig. 5. Scatterplot del rapporto dei principali parametri utili a distinguere *C. fluminea* (A, B), *C. leana* (C, D) e *C. cfr. fluminea* (E, F), su tutti gli esemplari delle popolazioni misurate (A, C, E) o sulla media degli esemplari di ciascuna popolazione (B, D, F).

respect to *C. fluminea* and *C. leana*, while the angle α is lower than *C. leana*.

This species or morphotype has not yet been assigned; it could coincide to one of the genetic strains already known in the literature, recognized by genetic investigation as present in other European countries (Renard et al., 2000; Pigneur et al., 2011, 2012, 2014a; Gomes et al., 2016; Peñarrubia et al., 2017).

Corbicula largillierti (Philippi, 1844) (Fig. 6. E-H)

This species is rather easy to identify by its small di-

mensions (less than 20 mm in length) and, especially, by several very thin ribs on external surface (about 18-27/cm at centre of each valve). The shell shape is rather equilateral and the whole inner surface of the valves is dark violet in colour, with concentric bands; in young specimens the narrow violet band in the umbo, always present in *C. fluminea*, is lacking, but a large dark band may also be present (Quiñonero-Salgado & López-Soriano, 2016a, 2016b; López-Soriano et al., 2018; Fig. 9 D-E). Its relative weight is much lighter than *C. fluminea*.

Corbicula leana Prime, 1867 (Fig. 8. I-P)

Characters	<i>Corbicula fluminalis</i> (Müller, 1774)	<i>Corbicula fluminea</i> (Müller, 1774)	<i>Corbicula</i> cf. <i>fluminea</i>	<i>Corbicula largillierti</i> (Philippi, 1844)	<i>Corbicula leana</i> Prime, 1867
Shell shape	Height, triangular	Oval-triangular, asymmetrical	Oval, rather equilateral	Rather rounding, rather equilateral	Oval or oval-triangular, wider , rather asymmetrical
Dimension mm (length x height)	Rather small: 10-24 x 12-26	Large: 22-36 x 20-33	Rather small: 16-28 x 14-26	Small: 13-19 x 12-18	Large: 24-35 x 21-30
Shell weight	Heavy	Rather heavy	Rather light	Light	Light
N° ribs/cm	Thin, 17-25	Spaced, 8-15	Spaced, 9-13	Thin, 18-27	Spaced, 7-11
Umbo	Very high	Rather high , with blue or violet vertical blotch , especially in juv.	Small; lacks the blue blotch or with a large blotch	Little high, rather smooth; lacks the blue blotch	Little high, uniform, orange (or pinkish), especially in juv.
Cardinal teeth	Very thick	Thick	Thick	Rather thin	Rather thin
Lateral teeth colour	Violet	White or coloured only on the tips	White or coloured only on the tips	Violet	Violet
External shell colour	Yellow or dark brown	Yellow, green or pale brown	Yellow-brown or dark brown	Yellow or dark brown	Yellow, green o dark brown
Inner shell colour	Dark violet	Whitish or pale violet	Whitish or pale violet	Dark violet with concentric bands	Yellow pale
Young	Violet vertical band	Violet narrow vertical band	No or large violet vertical band	Large violet vertical band	No vertical band

Table 4. Characters of *Corbicula* species living in Italy; in bold the main diagnostic characters.

Tab. 4. Caratteri delle diverse specie di *Corbicula* presenti in Italia; in grassetto i caratteri diagnostici principali.

1a- Subtriangular shell, higher than wide (or as high as wide); thick valves; regular and rather dense outer ribs; umbo prominent; inner valves dark purple in colour; lateral teeth uniform purplish coloured	<i>Corbicula fluminalis</i>
1b- Shell wider than high	2
2a- Small shell (<20 mm wide); thin valves; thin and dense outer ribs (18-27/cm); umbo with large central dark band; inner valves dark violet in colour with concentric bands; lateral teeth without purple spots at basis	<i>Corbicula largillierti</i>
2b- Shell usually larger; thickened and spaced outer ribs	3
3a- Asymmetric, oval-subtriangular shell (H/L = 0.91 on average) often with blackish spots; prominent umbo with narrow bluish vertical band (especially in young specimens); inner valves pale (whitish or pale violet); lateral teeth with purple spot at basis	<i>Corbicula fluminea</i>
3b- Almost symmetrical shell; umbo not prominent , without narrow vertical band	4
4a- Oval shell, not very large (H/L = 0.89 on average); umbo without coloured band or with large band; inner valves whitish or pale violet in colour; lateral teeth with purple spot at basis	<i>Corbicula</i> cf. <i>fluminea</i>
4b- Oval or oval-subtriangular shell, wider (H/L = 0.83 on average); umbo without coloured band; inner valves uniform yellowish in colour; lateral teeth purple (in young specimens just the initial part)	<i>Corbicula leana</i>

Table 5. Key for the determination of *Corbicula* species living in Italy; in bold the main diagnostic characters.

Tab. 5. Chiave per la determinazione delle diverse specie di *Corbicula* presenti in Italia; in grassetto i caratteri diagnostici principali.

This species is characterized by a wide, rather equilateral or sometimes asymmetrical shell shape, a very uniform orange umbo (in some specimens it may be also pinkish), spaced ribs (about 7-11/cm at centre of each valve) and by a pale yellow or pale orange coloration of the inner surface of the valves, while the lateral teeth are violet in color, as described by Quinonero-Salgado & López-Soriano (2016a, 2016b,

2017a) and by López-Soriano et al. (2018). The young shells do not have a narrow violet vertical band in the umbo and only the initial tract of the lateral teeth is violet in color (**Fig. 9. P-S**). The shell is consistently lighter and broader than *C. fluminea*, as also shown in the morphometric analysis; the ratios H/L and Hh/h are lower and the angle alpha wider than in *C. fluminea* and in *C. cf. fluminea*.

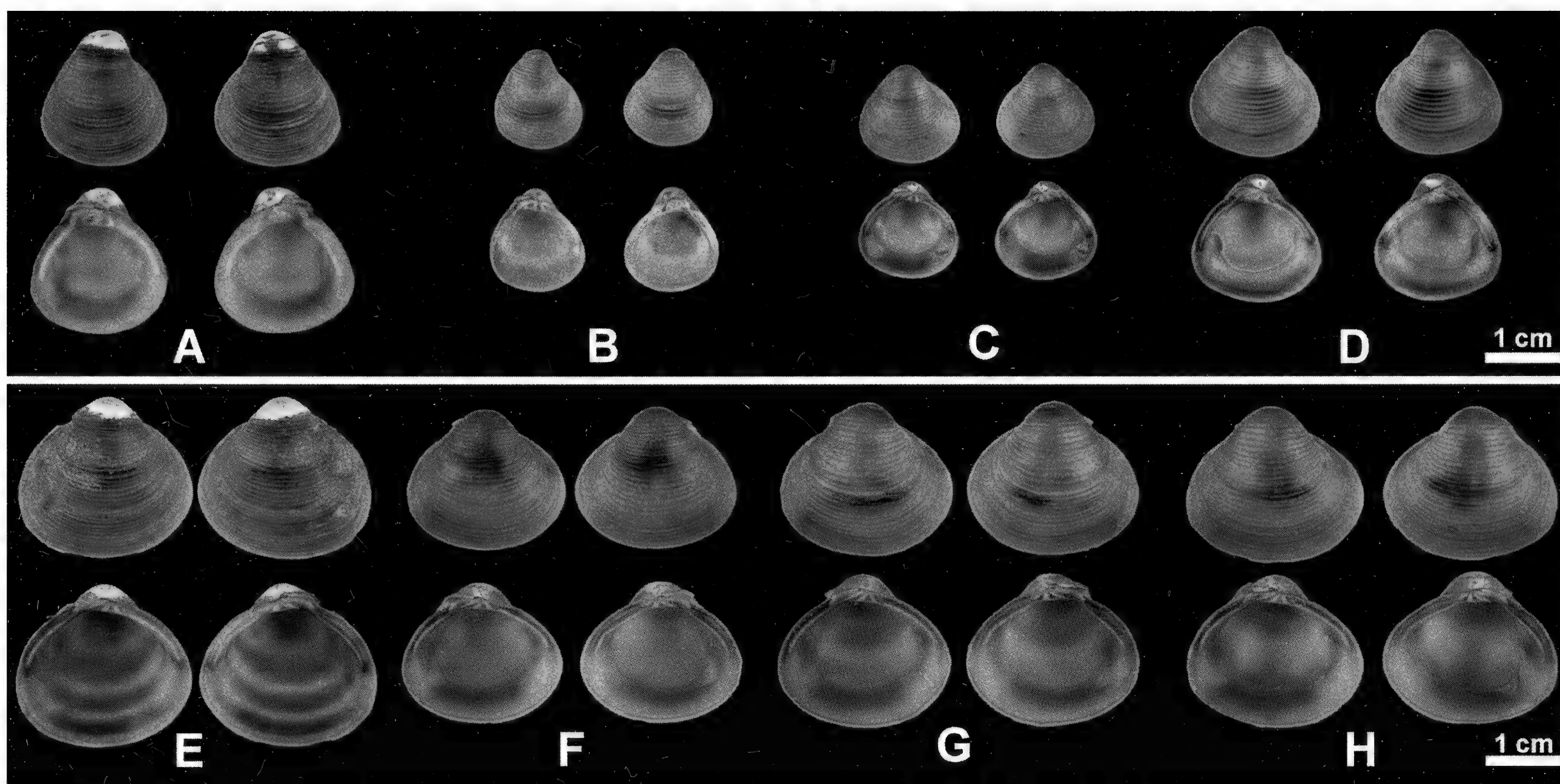


Fig. 6. Shells of *Corbicula fluminalis* (A-D) and *C. largillierti* (E-H) from Northern Italy; external surface of the valves and inner surface, in adult or sub-adult specimens. **A.** Mincio River at the bridge on the provincial road 21, Pozzolo (Marmirolo, Mantova, Lombardy), MZUF BC/60654; **B.** Lake at Passo di Lavazè (Varena, Trento, Trentino-Alto Adige), MZUF BC/60346; **C, D.** Lake Caldonazzo, Calceranica (Caldonazzo, Trento, Trentino-Alto Adige), MZUF BC/60347; **E.** Mincio River at the bridge on the provincial road 21, Pozzolo (Marmirolo, Mantova, Lombardy), MZUF BC/60655; **F-H.** Po River, Corbola (Corbola, Rovigo, Veneto), MZUF BC/60656.

Fig. 6. Conchiglie di *Corbicula fluminalis* (A-D) e *C. largillierti* (E-H) del nord Italia; superficie esterna delle valve e superficie interna, in esemplari adulti o subadulti. **A.** Fiume Mincio al ponte sulla strada provinciale 21, Pozzolo (Marmirolo, Mantova, Lombardia), MZUF BC/60654; **B.** Lago al Passo di Lavazè (Varena, Trento, Trentino-Alto Adige), MZUF BC/60346; **C, D.** Lago di Caldonazzo, Calceranica (Caldonazzo, Trento, Trentino-Alto Adige), MZUF BC/60347; **E.** Fiume Mincio al ponte sulla strada provinciale 21, Pozzolo (Marmirolo, Mantova, Lombardia), MZUF BC/60655; **F-H.** Fiume Po, Corbola (Corbola, Rovigo, Veneto), MZUF BC/60656.

The largest dimensions measured are: H 38 mm, L 44 mm (canal at San Giuliano Terme, Pisa).

Regarding the anatomical characters, some authors (Britton & Morton, 1979; Harada & Nishino, 1995; Korniushev, 2004; Glaubrecht et al., 2003; Reyna et al., 2013) have noticed modest differences in some species, especially about the coloration of inhalant and exhalant siphons and the shape and number of the tentacles surrounding the siphons opening. Comparing these elements in our material, they seem to be quite variable (**Figs 10-11; Table 6**): the number of tentacles of the inhalant siphon vary from 24 to 100 in *C. fluminea* and from 25 to 64 in *C. leana*, unbranched and arranged on approximately three rows, while in the exhalant siphon the tentacles are less numerous (20-30 in *C. fluminea* and 14-22 in *C. leana*) and arranged in one row. However, in *C. fluminea*, siphons are usually less pigmented externally than in *C. leana*. Furthermore, in *C. leana* a pigmented band is mostly present near the mantle edges, surrounding the siphons, dark brown in colour and very evident, while it is absent in *C. fluminea*. Instead, *C. largillierti* seems to be characterized by a weak pigmentation around the exhalant siphon, well pigmented internally exhalant siphon, tentacles on the inhalant siphon arranged in two rows. Some of these characters are not in agreement with those present in the literature and may have little taxonomic value.

Ecological notes

The species belonging to the genus *Corbicula* usually live in bottom with fine particle size, in riverine and lacustrine environments, preferring sandy areas with slowly flowing waters (Belanger et al., 1985; Schmidlin & Baur, 2007); but our original data confirm their partiality also for muddy substrates. Sometimes, they have been found in abundance also in pebbly substrate, but probably drifting from riverine tracts with thin substrates.

The number of specimens in every single population is very variable. In large rivers, subject to changes by floods, it is generally low and the specimens are located in places with favourite substrates and steady conditions: for example, in the Po River, populations of *Corbicula* settle in the muddy depressions among the stones, forming the river banks, and in lateral oxbows, while in the sandy bottom of the main stream only dead shells are present, carried by the water flow. Instead, in more stable watercourses, when *Corbicula* is present, it seems to be very abundant in the downstream stretches on the lake basins and in the river lower tracts (mesopotamal section). The populations tend to have an explosive development in the irrigation watercourses, as in the Lombardian areas fed by the waters of the Ticino River, or in the irrigation canals of Tuscany, where the bottom is altered by thick layers of *Corbicula* shells. Paganelli et al. (2018a), for example, indicate a density up

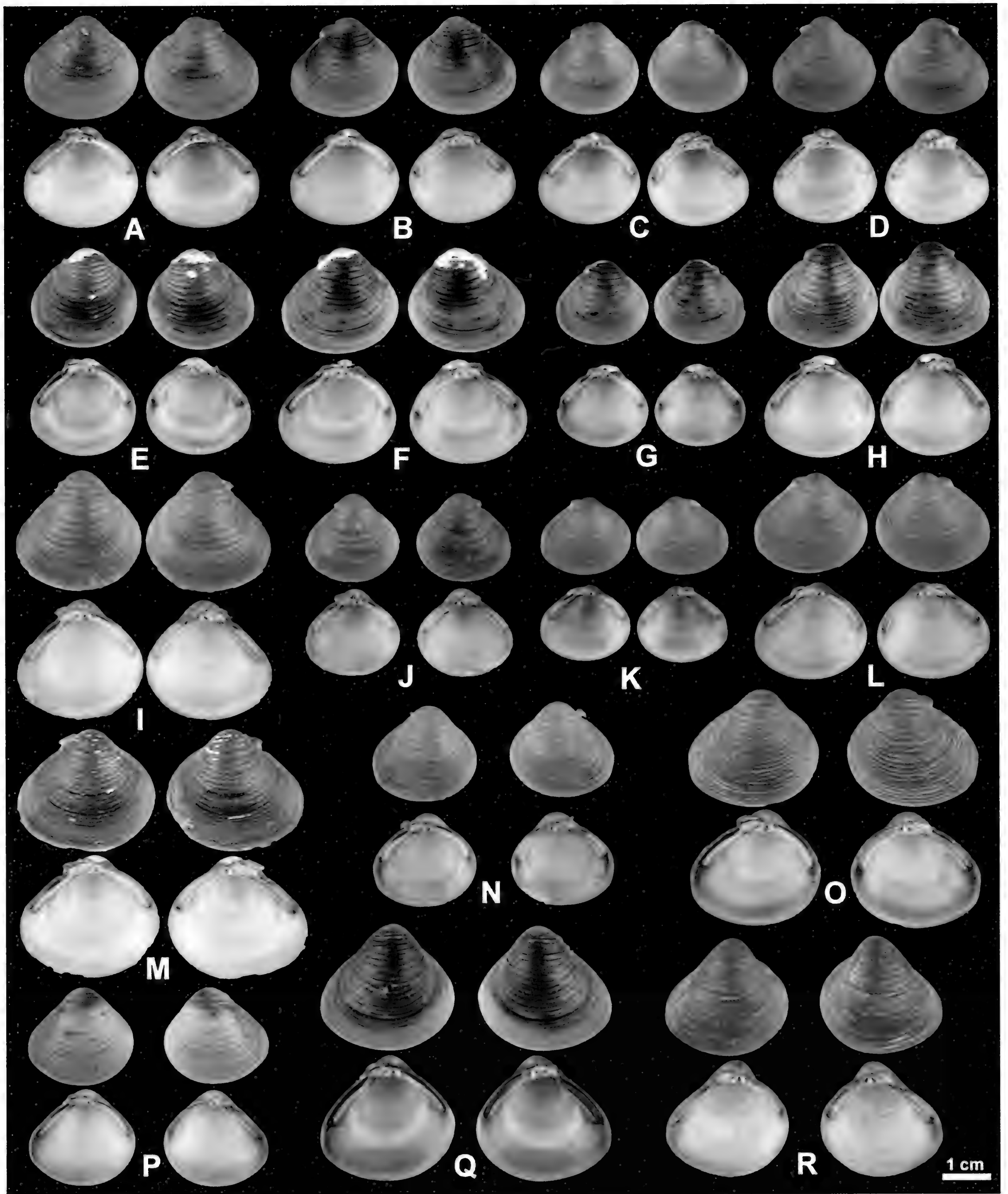


Fig. 7. Shells of *Corbicula fluminea* from Northern Italy and Tuscany; external surface of the valves and inner surface, in adult or sub-adult specimens. **A.** Lake Viverone, south-western bank, west of Cascina Nuova (Viverone, Biella, Piedmont), MZUF BC/60335; **B, C.** Lake Mergozzo, Il Portaiolo (Mergozzo, Verbania, Piedmont), MZUF BC/60337; **D.** Adda River 300 m upstream the bridge of Crotta d'Adda (Maccastorna, Lodi, Lombardy), MZUF BC/60343; **E, F.** Langosco Canal, locality Ponte Ticino (Galliate, Novara, Piedmont), MZUF BC/60338; **G, H.** Ticino River 1,5 km upstream the bridge of Bereguardo (Zerbolò, Pavia, Lombardy), MZUF BC/60340; **I, J.** Po River, 0,6 km upstream the Mezzano Bridge (Pieve Porto Morone, Pavia, Lombardy), MZUF BC/60339; **K, L.** Fossadone irrigation Ditch, 450 m east of Cascina Fasolina, west-north-west of Formigara (Formigara, Cremona, Lombardy), MZUF BC/60344; **M.** Oglio River near Contrada Fosio (Sarnico, Bergamo, Lombardy), MZUF BC/60465; **N, O.** Sile River, locality Torre Caligo (Jesolo, Venezia, Veneto), MZUF BC/59031; **P.** Arno River, Uliveto Terme (Vicopisano, Pisa, Tuscany), MZUF BC/60351; **Q.** Bisenzio River, 300 m upstream the join with Arno River (Signa, Firenze, Tuscany), MZUF BC/60646; **R.** Arno River at the bridge between Zambra and Caprona (Cascina, Pisa, Tuscany), MZUF BC/60352.

Fig. 7. Conchiglie di *Corbicula fluminea* del nord Italia e della Toscana; superficie esterna delle valve e superficie interna, in esemplari adulti o sub-adulti. **A.** Lago di Viverone, riva sud-occidentale, a ovest di Cascina Nuova (Viverone, Biella, Piemonte), MZUF BC/60335; **B, C.** Lago di Mergozzo, Il Portaiolo (Mergozzo, Verbania, Piemonte), MZUF BC/60337; **D.** Fiume Adda 300 m a monte del ponte di Crotta d'Adda (Maccastorna, Lodi, Lombardia), MZUF BC/60343; **E, F.** Canale Langosco, località Ponte Ticino (Galliate, Novara, Piemonte), MZUF BC/60338; **G, H.** Fiume Ticino 1,5 km a monte del ponte di Bereguardo (Zerbolò, Pavia, Lombardia), MZUF BC/60340; **I, J.** Fiume Po, 0,6 km a monte del ponte di Mezzano (Pieve Porto Morone, Pavia, Lombardia), MZUF BC/60339; **K, L.** Fosso di Fossadone, 450 m a est di Cascina Fasolina, a ovest-nord ovest di Formigara (Formigara, Cremona, Lombardia), MZUF BC/60344; **M.** Fiume Oglio presso Contrada Fosio (Sarnico, Bergamo, Lombardia), MZUF BC/60465; **N, O.** Fiume Sile, località Torre Caligo (Jesolo, Venezia, Veneto), MZUF BC/59031; **P.** Fiume Arno, Uliveto Terme (Vicopisano, Pisa, Toscana), MZUF BC/60351; **Q.** Fiume Bisenzio, Bisenzio, 300 m a monte della confluenza con l'Arno (Signa, Firenze, Toscana), MZUF BC/60646; **R.** Fiume Arno al ponte tra Zambra e Caprona (Cascina, Pisa, Toscana), MZUF BC/60352.

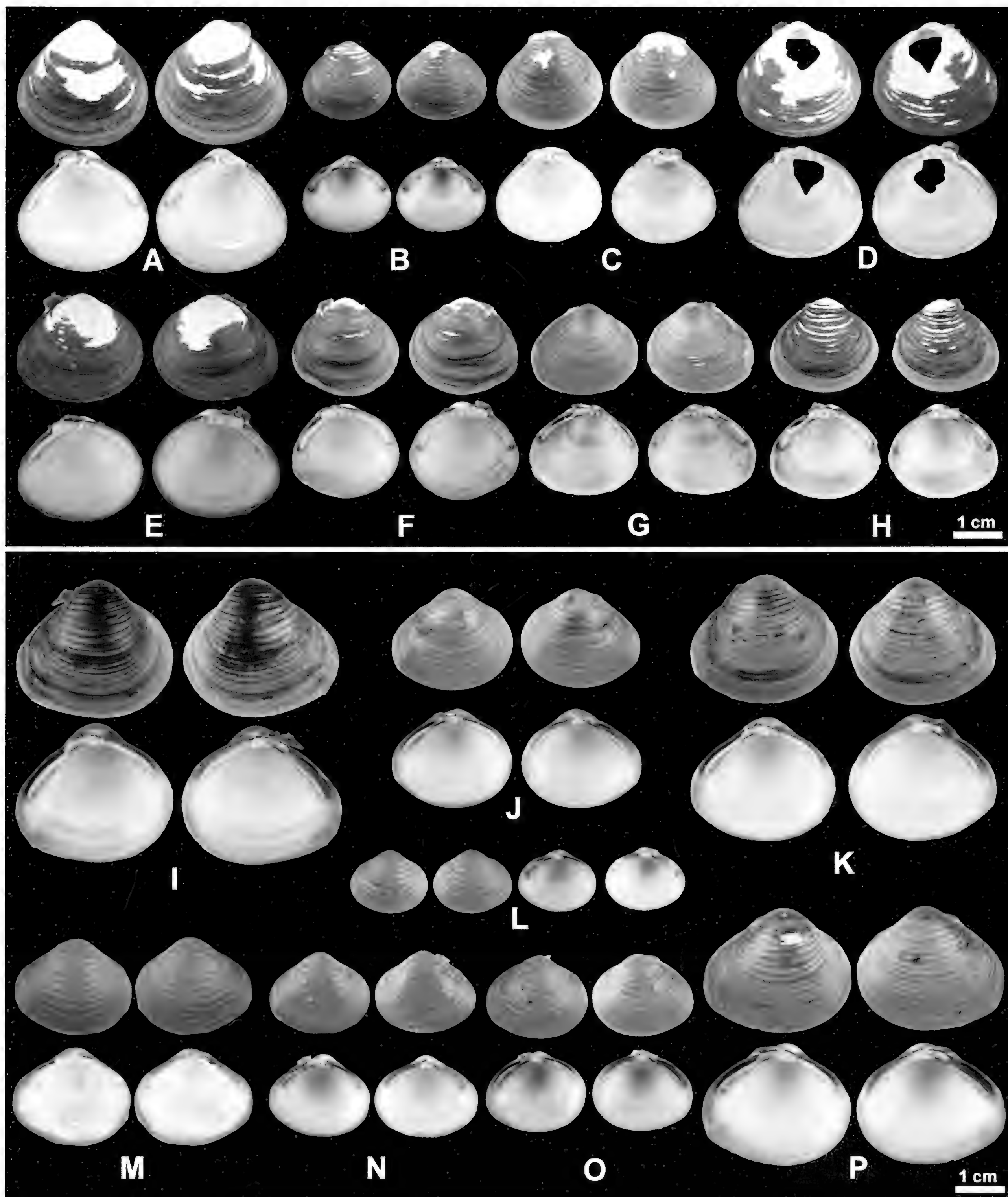


Fig. 8. Shells of *Corbicula* cf. *fluminea* (A-H) from Lombardy and *C. leana* (I-P) from Northern Italy and Tuscany; external surface of the valves and inner surface, in adult or sub-adult specimens. **A, B.** Grande Waterway, Castelletto di Cuggiono (Cuggiono, Milano, Lombardy), MZUF BC/59052; **C, D.** Marinone Canal, south-west of Nosate (Nosate, Milano, Lombardy), MZUF BC/59053; **E, F.** Adda River 1,2 km south of the Santuario della Divina Maternità, Trezzo sull'Adda (Vaprio d'Adda, Milano, Lombardy), MZUF BC/60342; **G, H.** Oglio River near Cascina Berlucci, just downstream the bridge on the provincial road 11, between Calcio and Urago d'Oglio (Calcio, Bergamo, Lombardy), MZUF BC/60345; **I-K.** Storto di Sant'Ambrogio Brook, Sant'Ambrogio (Trebaseleghe, Padova, Veneto), MZUF BC/60348; **L.** Ticino River 1,5 km upstream the bridge of Bereguardo (Zerbolò, Pavia, Lombardy), MZUF BC/60341; **M, N.** Serchio River downstream the bridge in front of Ripafratta (Vecchiano, Pisa, Tuscany), MZUF BC/60349; **O, P.** Drain along the state road 12, in front of the bridge in Via delle Sorgenti, south of San Giuliano Terme (San Giuliano Terme, Pisa, Tuscany), MZUF BC/60350.

Fig. 8. Conchiglie di *Corbicula* cf. *fluminea* (A-H) dalla Lombardia e *C. leana* (I-P) dal nord Italia e dalla Toscana; superficie esterna delle valve e superficie interna, in esemplari adulti o subadulti. **A, B.** Naviglio Grande, Castelletto di Cuggiono (Cuggiono, Milano, Lombardia), MZUF BC/59052; **C, D.** Canale Marinone, a sud-ovest di Nosate (Nosate, Milano, Lombardia), MZUF BC/59053; **E, F.** Fiume Adda 1,2 km a sud del Santuario della Divina Maternità, Trezzo sull'Adda (Vaprio d'Adda, Milano, Lombardia), MZUF BC/60342; **G, H.** Fiume Oglio presso Cascina Berlucci, appena a valle del ponte sulla strada provinciale 11, tra Calcio e Urago d'Oglio (Calcio, Bergamo, Lombardia), MZUF BC/60345; **I-K.** Rio Storto di Sant'Ambrogio, Sant'Ambrogio (Trebaseleghe, Padova, Veneto), MZUF BC/60348; **L.** Fiume Ticino 1,5 km a monte del ponte di Bereguardo (Zerbolò, Pavia, Lombardia), MZUF BC/60341; **M, N.** Fiume Serchio a valle del ponte di fronte a Ripafratta (Vecchiano, Pisa, Toscana), MZUF BC/60349; **O, P.** Fosso lungo la statale 12, di fronte al ponte in Via delle Sorgenti, a sud di San Giuliano Terme (San Giuliano Terme, Pisa, Toscana), MZUF BC/60350.

to 1,500 specimens/m² in the lotic waters of River Ticino basin. Even in the lakes, in presence of suitable bottom, the *Corbicula* populations can explode massively: for example, in Lake Maggiore, densities even higher than 2,500 specimens/m² have been recorded (Guarneri, 2013). In Europe, densities even higher than 16,000 living specimens/m² are known (Hubenov et al., 2013), while a large number of empty dead shells accumulate in the sediments, altering their composition (Corenblit

et al., 2013; Quiñonero-Salgado & López-Soriano, 2014). Finally, even greater densities were found in North America that is up to 131,000 specimens/m² (Britton & Morton, 1982).

It is not uncommon to find *Corbicula* species living together in the same water body: in Lake Garda, for example, four different *Corbicula* species are known in southern areas of this wide lake (López-Soriano et al., 2018). Three different taxa (*C. fluminea*, *C. fluminalis* and

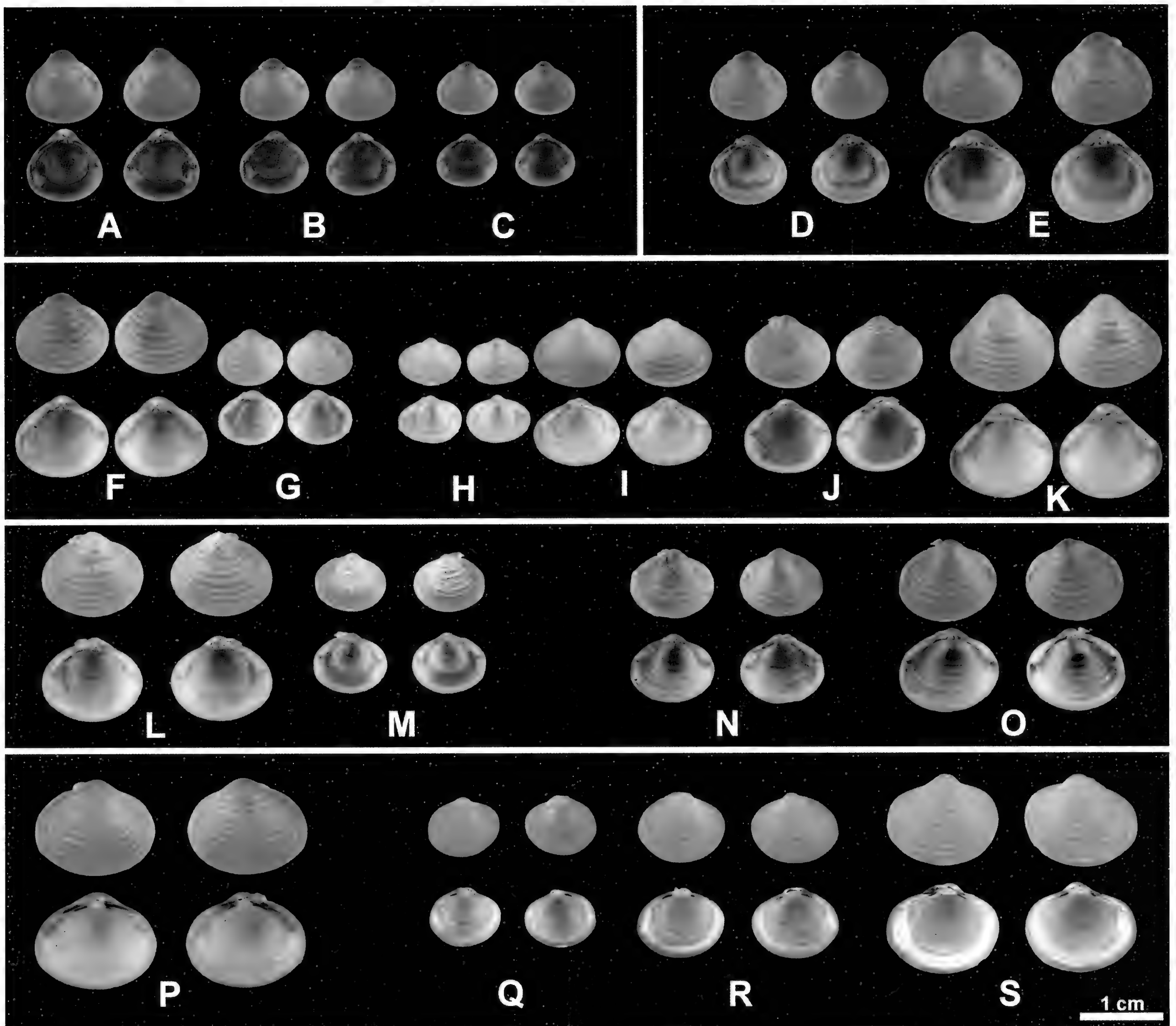


Fig. 9. Young shells of *Corbicula fluminalis* (A-C), *C. largillierti* (D, E), *C. fluminea* (F-K), *C. cf. fluminea* (L-O) and *C. leana* (P-S) from Northern Italy and Tuscany; external surface of the valves and inner surface. A-C. Lake Caldonazzo, Calceranica (Caldonazzo, Trento, Trentino-Alto Adige), MZUF BC/60347; D, E. Po River, Corbola (Corbola, Rovigo, Veneto), MZUF BC/60656; F, G. Ticino River 1.5 km upstream the bridge of Bereguardo (Zerbolò, Pavia, Lombardy), MZUF BC/60340; H, I. Sile River, locality Torre Caligo (Jesolo, Venezia, Veneto), MZUF BC/59030; J. Lake Mergozzo, Il Portaiolo (Mergozzo, Verbania, Piedmont), MZUF BC/60337; K. Arno River, Uliveto Terme (Vicopisano, Pisa, Tuscany), MZUF BC/60351; L, M. Crosio Ditch near the Santuario della Madonna della Prierà, west of Biandrate (Biandrate, Novara, Piedmont), MZUF BC/60336; N, O. Adda River 1.2 km south of the Santuario della Divina Maternità, Trezzo sull'Adda (Vaprio d'Adda, Milano, Lombardy), MZUF BC/60342; P. Ticino River 1.5 km upstream the bridge of Bereguardo (Zerbolò, Pavia, Lombardy), MZUF BC/60341; Q-S. Serchio River at the bridge between P.te Nuovo, S.ta Maria a Colle (Lucca, Tuscany), MZUF BC/59047.

Fig. 9. Giovani conchiglie di *Corbicula fluminalis* (A-C), *C. largillierti* (D, E), *C. fluminea* (F-K), *C. cf. fluminea* (L-O) e *C. leana* (P-S) del nord Italia e della Toscana; superficie esterna delle valve e superficie interna. A-C. Lago di Caldonazzo, Calceranica (Caldonazzo, Trento, Trentino-Alto Adige), MZUF BC/60347; D, E. Fiume Po, Corbola (Corbola, Rovigo, Veneto), MZUF BC/60656; F, G. Fiume Ticino 1,5 km a monte del ponte di Bereguardo (Zerbolò, Pavia, Lombardia), MZUF BC/60340; H, I. Fiume Sile, località Torre Caligo (Jesolo, Venezia, Veneto), MZUF BC/59030; J. Lago di Mergozzo, Il Portaiolo (Mergozzo, Verbania, Piemonte), MZUF BC/60337; K. Fiume Arno, Uliveto Terme (Vicopisano, Pisa, Toscana), MZUF BC/60351; L, M. Fosso Crosio vicino al Santuario della Madonna della Prierà, ad ovest di Biandrate (Biandrate, Novara, Piemonte), MZUF BC/60336; N, O. Fiume Adda 1,2 km a sud del Santuario della Divina Maternità, Trezzo sull'Adda (Vaprio d'Adda, Milano, Lombardia), MZUF BC/60342; P. Fiume Ticino 1,5 km a monte del ponte di Bereguardo (Zerbolò, Pavia, Lombardia), MZUF BC/60341; Q-S. Fiume Serchio al Ponte Nuovo, S.ta Maria a Colle (Lucca, Toscana), MZUF BC/59047.

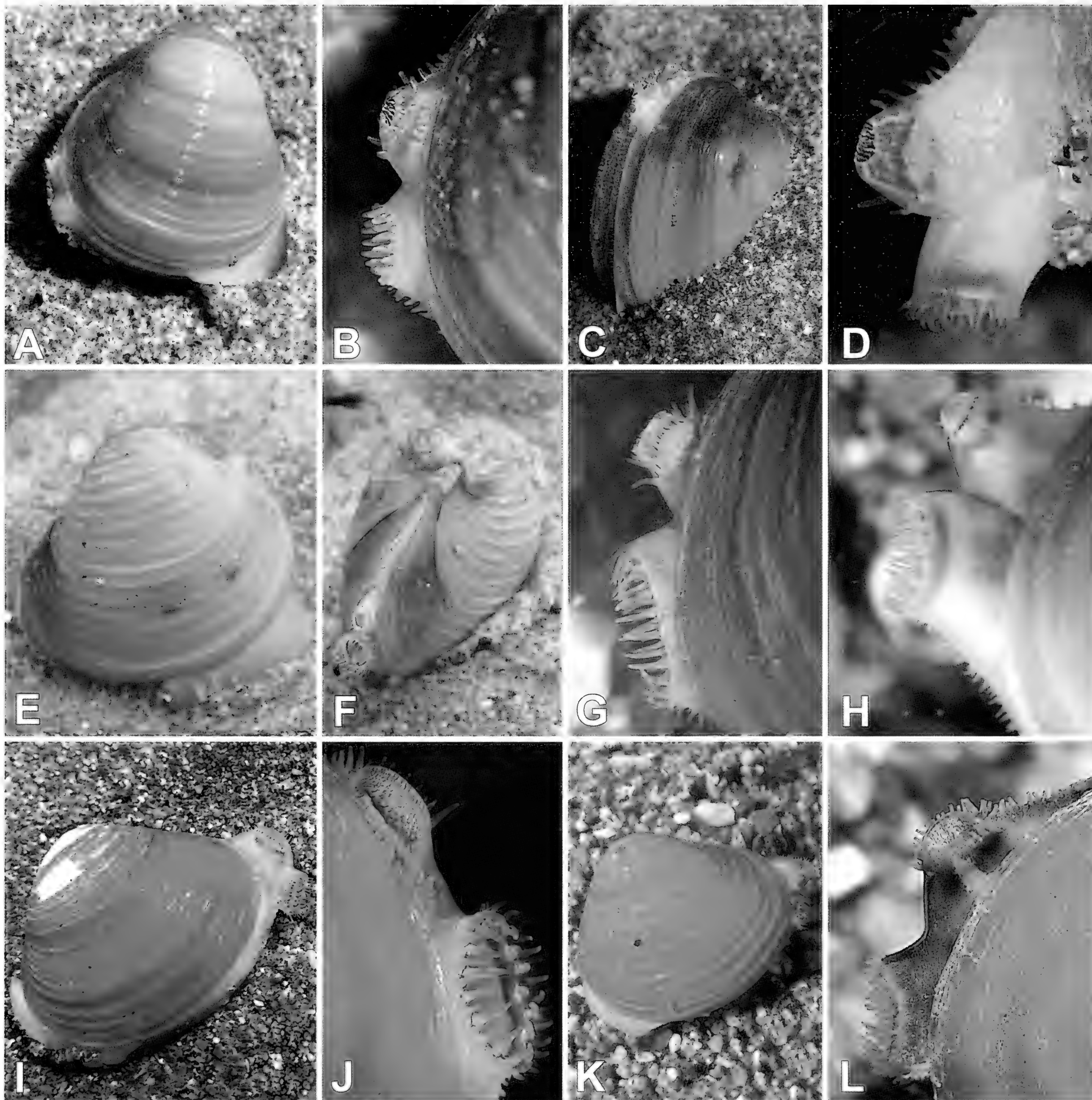


Fig. 10. Living specimens of *Corbicula fluminalis* (A, B), *C. largillierti* (C, D), *C. fluminea* (E-H), *C. cf. fluminea* (I, J) and *C. leana* (K, L); complete specimens (A, C, E, F, I, K) and magnification of siphons (B, D, G, H, J, L). Specimens from: Lake Garda off shore Cisano, Bardolino, Veneto (A, B); Po River, Corbola, Rovigo, Veneto (C, D); Lake Mergozzo, Biella, Piedmont (E-F); Ceresone River at the bridge of Via Ceresone, Poiana di Granfion, Grisignano di Zocco, Vicenza, Veneto (G); Adda River 1.2 km south of the Santuario della Divina Maternità, Vaprio d'Adda, Milano, Lombardy (H); Oglio River upstream the bridge between Rudiano and Pumenengo, Brescia, Lombardy (I, J); Rio Storto near Sant'Ambrogio, Sant'Ambrogio, Padova, Veneto (K, L).

Fig. 10. Esemplari viventi di *Corbicula fluminalis* (A, B), *C. largillierti* (C, D), *C. fluminea* (E-H), *C. cf. fluminea* (I, J) e *C. leana* (K, L); esemplari completi (A, C, E, F, I, K) e ingrandimento dei sifoni (B, D, G, H, J, L). Esemplari provenienti da: Lago di Garda al largo di Cisano, Bardolino, Veneto (A, B); Fiume Po, Corbola, Rovigo, Veneto (C, D); Lago di Mergozzo, Biella, Piemonte (E-F); Fiume Ceresone al ponte di Via Ceresone, Poiana di Granfion, Grisignano di Zocco, Vicenza, Veneto (G); Fiume Adda 1.2 km a sud del Santuario della Divina Maternità, Vaprio d'Adda, Milano, Lombardia (H); Fiume Oglio a monte del ponte tra Rudiano e Pumenengo, Brescia, Lombardia (I, J); Rio Storto vicino Sant'Ambrogio, Sant'Ambrogio, Padova, Veneto (K, L).

C. largillierti), have been collected sympatric by the authors in the same site, as in Lake Garda in locality Cantarane, Punta Gro (Sirmione, Brescia) or in Lido Ronchi (Castelnuovo del Garda, Verona), and up to four (also *C. leana*) at Cisano (Bardolino, Verona). Generally, in lotic environments, the most frequent species are *C. fluminea* and *C. leana* and they may live together. In these cases, one species is often dominant, while the second one is less frequent. Moreover, the distribution

of these taxa is often placed in different portions of the same river course. Rarely, up to three different species were observed in the same collecting site, as in the final stretch of the Po River course, in Rovigo province, where *C. fluminea*, *C. largillierti* and *C. leana* live sympatrically, but with a little number of specimens. In Japan, an event of competition has been observed between the introduced *C. fluminea* and the autochthonous *C. leana*, which lead to the disappearance of the latter (Ishibashi

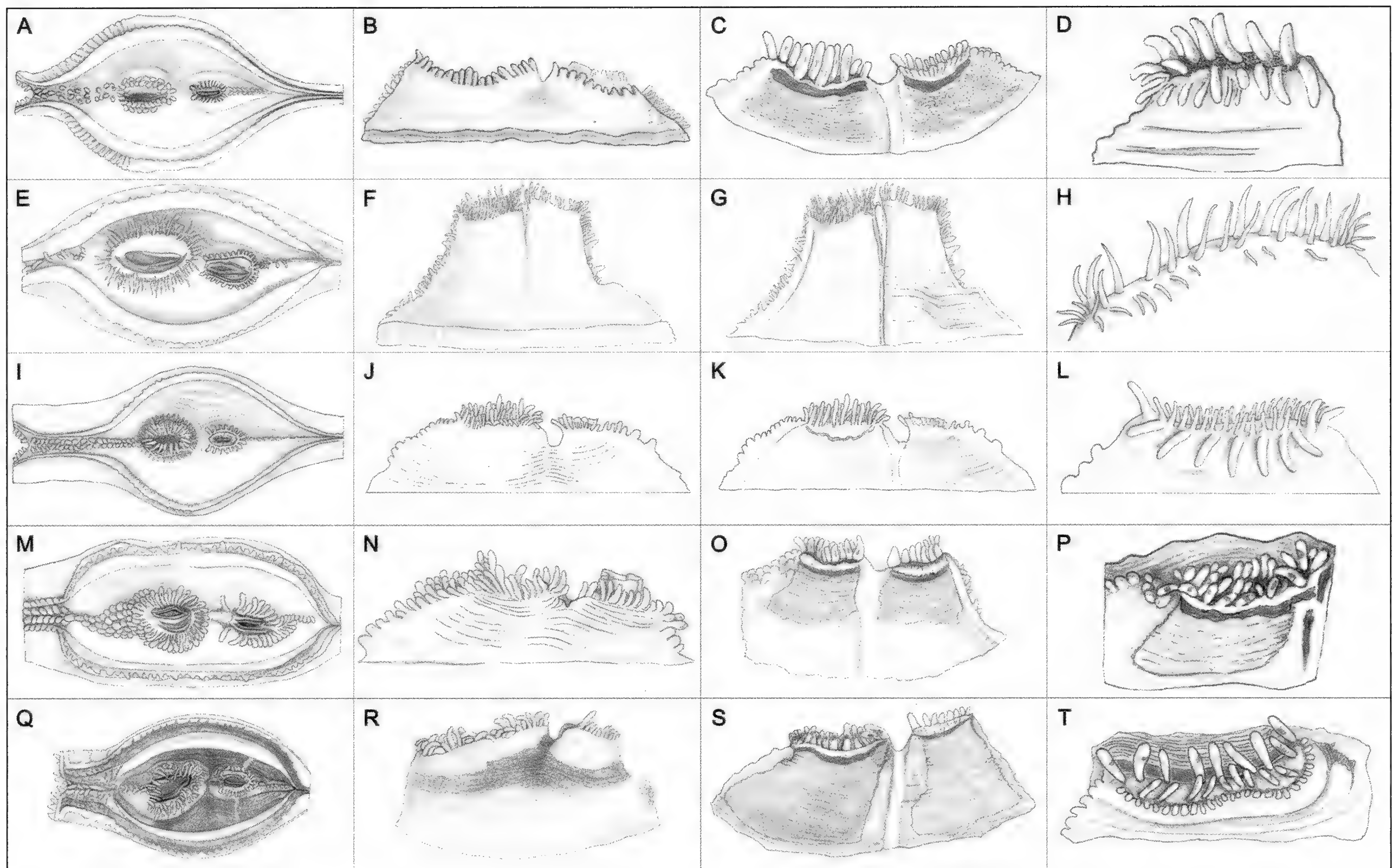


Fig. 11. Siphons (left: inhalant siphon; right: exhalant siphon) and mantle edge surrounding the siphons in *Corbicula fluminalis* (A-D), *C. fluminea* (E-H), *C. cf. fluminea* (I, L), *C. largillierti* (M-P) and *C. leana* (Q-T). A, E, I, M, Q. Siphons from outside and mantle edge surrounding the siphons from upper view. B, F, J, N, R. siphons from external lateral view. C, G, K, O, S. Siphons from inner lateral view. D, H, L, P, T. Disposition of the tentacles on inhalant siphon edge, from external lateral view (D, H, T) or from inner lateral view (L, P) view. Specimens from: Lake Garda off shore Cisano, Bardolino, Verona, Veneto (A, B); Lake Caldonazzo, Calceranica, Caldonazzo, Trento, Trentino-Alto Adige (C, D); Brenta Waterway downstream Valmarana, Mira, Venezia, Veneto (E-H); Crosio Ditch near the Santuario della Madonna della Prieria, west of Biandrate, Novara, Piedmont (I-L); Po River, Corbola, Rovigo, Veneto (M-T).

Fig. 11. Sifoni (a sinistra: sifone inalante; a destra: sifone esalante) e margine del mantello che circonda i sifoni in *Corbicula fluminalis* (A-D), *C. fluminea* (E-H), *C. cf. fluminea* (I, L), *C. largillierti* (M-P) e *C. leana* (Q-T). A, E, I, M, Q. Sifoni dall'esterno e margine del mantello che circonda i sifoni visto dall'alto. B, F, J, N, R. Sifoni in visione esterna laterale. C, G, K, O, S. Sifoni in visione interna laterale. D, H, L, P, T. disposizione dei tentacoli sul margine del sifone inalante, in visione esterna laterale (D, H, T) o interna laterale (L, P). Esempi provenienti da: Lago di Garda al largo di Cisano, Bardolino, Verona, Veneto (A, B); Lago di Caldonazzo, Calceranica, Caldonazzo, Trento, Trentino-Alto Adige (C, D); Naviglio Brenta a valle di Valmarana, Mira, Venezia, Veneto (E-H); Canale Crosio vicino al Santuario della Madonna della Prieria, a ovest di Biandrate, Novara, Piemonte (I-L); Fiume Po, Corbola, Rovigo, Veneto (M-T).

& Komaru, 2003), but in Italy, although it is still too early to draw conclusions in consideration of their quite recent colonisation, both species seem to thrive.

Obviously, dense populations of *Corbicula* clams have a significant ecological impact: indeed, because these molluscs are strong filterers of phytoplankton and suspended particulates, they enter in competition with other native clams (Vaughn & Spooner, 2006; Ferreira-Rodríguez et al., 2018) and they alter the nutrient cycle. Moreover, many decaying dead specimens cause the development of toxic substances and their empty shells, accumulating in large quantities, modify the substrate composition as well as entailing economic damage to hydroelectric power plant or irrigation canals (McMahon, 1982; Cherry et al., 2005; Karatayev et al., 2007; Pigneur et al., 2014b). However, substantial alterations have been observed especially in Northern America; in Europe the impact of the clams to the economy, does not seem to be yet too massive (Rosa et al., 2011).

Studies conducted in North America and Portugal show a clear change in the macroinvertebrate commu-

nities, after colonization by *Corbicula* (Hakenkamp et al., 2001; Pereira et al., 2017), while in a German lake a substrate transformation has been noticed, due to the large number of empty shells accumulated in the bottom (Werner & Rothhaupt, 2007). Moreover, when *Corbicula* is present with high density populations, it causes significant decrease in the indigenous communities (Sousa et al., 2008b) and bioturbation in the sediments (Majdi et al., 2014). Our original observations seem to indicate a small effect on the macroinvertebrate community: for example, in the largest Prealps lakes, a clear drop in the abundance of *Dreissena polymorpha* (Pallas, 1771) (another alien bivalve, which invaded the same basins some years before *Corbicula*) has been observed, probably as the result of the food competition; indeed, although *Dreissena* settles on hard substrates while *Corbicula* on mobile ones, both species filter phytoplankton. In running water of northern Italy, where *Corbicula* species are abundant, unionids seem mostly rare or absent, but the possible competition has not been verified. In Lake Maggiore a strong decline of *Unio* density has been observed, with a reduction of about 75% of speci-

mens after *Corbicula* establishment, by competition for space and food (Guarneri et al., 2013). In the benthonic communities of macroinvertebrates, based on macrobenthos data recorded by ARPA Lombardia, referred to the sampling carried out on the regional monitoring network in 2009-2018, a significant variation in the presence and abundance of other taxa, which may depend in the presence and abundance of *Corbicula* (present in 22.6% of the samplings in plain area), does not seem to be evident. Only in non-compromised situations (I or II Quality Class based on the STAR_ICMi macrobenthic index of Ministerial Decree 260/2010), there is a slight decrease in biodiversity (assessed by the Shannon diversity index), but only with high *Corbicula* frequencies. Considering the mollusc taxocoenosis, which is generally quite poor in number of taxa if compared to other macroinvertebrates taxocoenosis, assessed by PCA analysis, no particular groupings are evident based on this community. However, *Corbicula* is the dominant

element on the first axis, *Potamopyrgus* Stimpson, 1865, on the second axis, *Theodoxus* Montfort, 1810, and *Bithynia* Leach, 1818, on the third and *Physella* Haldeman, 1842, on the fourth (cumulative percentage of the variance respectively of 26%, 42%, 57%, 70%). Thus, the influence of alien species (*Corbicula*, *Potamopyrgus*, *Physella*) in characterizing the taxocoenosis is evident. Instead, a correlation with the Water Quality Class (visible only on the 3rd axis in relation to the greater sensitivity of *Bithynia* and *Theodoxus*) is not very evident, probably due to the poor sensitivity of the molluscs taxocoenosis. Even in Veneto, by the data of macroinvertebrates recorded by ARPA Veneto, referred to the sampling carried out on the regional monitoring network in the same years, the presence of *Corbicula* does not seem relevant for benthonic communities, but in this region the presence of *Corbicula* is scarce (5.5% of the samplings in plain area). In any case, because the invasion and the spread by

Characters	<i>C. fluminalis</i>	<i>C. fluminea</i>	<i>C. cf. fluminea</i>	<i>C. largillierti</i>	<i>C. leana</i>
Pigmentation of mantle edge surrounding the siphons	Pale with brown or light-yellow band	Pale without pigmentation band	Pale with brown band or without pigmentation band	Pale with brown band or without pigmentation band	Brown with brown band or without pigmentation band
External pigmentation of inhalant siphon	No pigmentation	No pigmentation	Brown band near the middle or without pigmentation	No or weak pigmentation	Pale brown with brown band near the base
External pigmentation of exhalant siphon	No pigmentation	No pigmentation	Brown band near the base or without pigmentation	No or weak pigmentation	Brown band near the base
Internal pigmentation of inhalant siphon	Whitish, with one yellow band under the base of tentacles	No pigmentation	Yellow, with one brown band under the base of tentacles	Yellow, with two brown bands: the first at the base of the tentacles, the second one just below	Yellow, with a brown band under the base of tentacles or without pigmentation
Internal pigmentation of exhalant siphon	Yellow, with one brown band under the base of tentacles	No pigmentation	Yellow	Yellow, with two brown bands: the first at the base of the tentacles, the second one just below	Yellow or light yellow, with a brown band under the base of tentacles
Disposition of tentacles on inhalant siphon	Two or three rows, subequal in number, internally larger, externally smaller	Three rows subequal in number, internally larger, externally smaller	Three rows, internally larger and lower in number, externally smaller	Two rows, subequal in number and dimension	Three rows, internally larger and lower in number, externally smaller
Disposition of tentacles on exhalant siphon	One row	One row	One row	One row	One row
Shape of tentacles in inhalant siphon	Unbranched, not pointed	Unbranched, pointed	Unbranched, pointed or not	Unbranched, not pointed	Unbranched, not pointed
Shape of tentacles in exhalant siphon	Unbranched, not pointed	Unbranched, not pointed	Unbranched, not pointed	Unbranched, not pointed	Unbranched, not pointed
Pigmentation band of tentacles in inhalant siphon	Yes (only on internal row) or not	Weak (only on internal row) or not	Yes (only on internal row) or not	Yes (only on internal row) or not	Yes (only on internal and median rows) or not
Pigmentation band of tentacles in exhalant siphon	No	No	No	No	No
Number of tentacles in inhalant siphon	36-54	24-100	40-98	26-56	25-64
Number of tentacles in exhalant siphon	18-24	20-30	16-26	20-24	14-22

Table 6. Characters observed on siphons and mantle edge surrounding the siphons in *Corbicula* species living in Italy.

Tab. 6. Caratteri osservati sui sifoni e sull'orlo del mantello che circonda i sifoni nelle diverse specie di *Corbicula* presenti in Italia.

Corbicula is a recent phenomenon, it will be necessary more time to fully evaluate the effects of its presence in the impacted areas. Furthermore, these bivalves preferably frequent watercourses altered by the hydromorphological works or by water pollution, so the biocoenosis previously present were already compromised.

Corbicula species seem to be limited by low temperatures (Müller & Baur, 2011; Basen et al., 2017) and to be rather demanding with regard the water quality, especially with respect to the oxygen level; indeed, they do not seem to proliferate in sites with anoxic sediments, preferring well oxygenated shallow water habitats (Belanger et al., 1985; Matthews & McMahon, 1999). The data collected in the present research, however, show a good resistance of these molluscs towards water pollution.

The data on the presence/absence and abundance of *Corbicula*, detected by ARPA Lombardia, do not show any correlation with the quality judgments on the Ecological State or Chemical State, expressed according to the procedures established by the Ministerial Decree 260/2010. Instead, *Corbicula* is present indifferently in watercourses having an ecological status of high quality (Elevated) to a lower one (Bad). However, in Bad ecological state, the percentage of relative presence of *Corbicula* in the samplings suffers a susceptible decline (7% compared to 26-31% in the classes from Good to Poor). In the same way, *Corbicula* is present in water bodies having both Good and Not Good Chemical Status. Its absence in water bodies with No Good Chemical Status would seem to be independent to the presence of particular pollutants. Even in Veneto, based on the data by ARPA Veneto, *Corbicula* is present indifferently in watercourses having an ecological status of high quality to a lower one; in bad status *Corbicula* is still well present.

As evidenced by the distribution map in Lombardy (Fig. 12), the presence of *Corbicula* depends on the hydromorphological characteristics of the watercourses. Instead, it is always absent in the Alpine/Prealpine areas and also in the tributaries on the right bank of the River Po in the plain area (Oltrepò Pavese), due to the intermittent water balance and coarse substrate, not adequate for the presence of these clams. The only exceptions in the Prealpine areas are represented by the finding of *Corbicula* in Bardello and Margorabbia streams, both affluent of Lake Maggiore, where the presence of the clams has been ascertained since 2013 (ARPA Lombardia, 2019). Even in Veneto *Corbicula* is spread mainly in the plain area, especially in southern Veneto, but is not very spread (Fig. 12).

In Tuscany *Corbicula* is much less widespread; in the main watercourses it is known only for the lower section of Serchio, Arno and Bisenzio rivers. Based on data published by Regional Agency for Environment (ARPAT, 2019a, 2019b), the lower section of Serchio River falls under the Ecological Status variable from Good to Poor, depending by sections and years of sampling (from 2010 to 2017), and the Chemical Status is Good. In the lower course of Bisenzio River, in province of Prato, where the Regional Agency for Environment studied

Corbicula from 2016 to 2019, the water quality is Not Good concerning the Chemical Status, due to the presence of mercury and other toxic substances (phthalates and perfluorinated compounds), and Poor concerning the Ecological Status, due to the quite altered macroinvertebrates communities (ARPAT, 2019b). The lower section of Arno River is even more compromised, with an Ecological State mostly Poor or Bad and a Chemical State almost always Not Good. Even in Tuscany, therefore, we confirm what was observed in the watercourses of Lombardy, that is, the strong resistance of *Corbicula* in situations of strong pollution.

An important degree of anoxia causes a strong population decline. For example, in the Lake Viverone (province of Biella), after a strong algal bloom, an extensive anoxic sediment led to the death of the settled population, even at low depth. However, thanks to their high fertility and rapid growth, the species can quickly re-colonize the environments when conditions become favourable.

Several factors influence the control of *Corbicula* populations and their mortality, such as temperatures, dissolved oxygen, silt loads, acidic waters, pollution, bacterial and viral infections, parasites, predators, genetic changes, interspecific and intraspecific competition (Sikel, 1986). Among these factors that lead to decline or death, the excessive exploitation of food resources and the presence of toxic contaminations seem to be prevalent (Sikel, 1986; Mouthon, 2001a, 2001b, 2003). Massive deaths of *Corbicula*, which occur in presence of elevated temperatures, lack of nutrients and anoxic sediments, cause drastic alterations of biocoenosis, due to the decomposition and the release of toxic substances (Ilarri et al., 2011). A special case is due to the dissolution and perforation of the shell in the umbonal region, in presence of acidic waters; *Corbicula* is more susceptible to this phenomenon than unionids, because it has no conchiolin layers in the shell (Kat, 1982). This fact has been observed in Ticino River and neighbouring waters, especially in the upper plain where, in some sites, almost all adult shells collected in the sediments have apical holes due to corrosion. Paganelli et al. (2018b) have already studied this phenomenon in the waters of two watercourses bordering the Ticino River, finding frequent apical corrosion in adult shells, but without the formation of holes. In this case the authors exclude that the phenomenon is due to the acidity of the water, but the cause is not yet clear and, perhaps, could be due to a disease or parasitic infestation. Anyway, the relationship between the AWWA (IA) index of water aggressivity (calculated through the pH, alkalinity and calcium hardness data) and the shell corrosion is evident. The greatest umbonal corrosion has been registered in the Terdoppio River populations (IA 11.9 in average, moderately aggressive water), Vecchio and Grande waterways and Marinone Canal, powered by the first tract of the Ticino River water (where the IA is 11.2 in average in Province of Varese, moderately aggressive water). Least corrosion has been registered in the populations of lower Ticino River (IA 11.9 in average in province of

Pavia, moderately aggressive water), Adda River (IA 12.1 in average, no aggressive water) and Oglio River (IA 12.5 in average, no aggressive water), while weak or almost no corrosion has been observed in Mincio River (IA 12.4 in average, no aggressive water) and in Po River in Lombardy (IA 12.4 in average, no aggressive water). From west to east the rivers show a lesser index of aggressivity, according to the lithological substrate, richer in limestone in the eastern Pre-Alps.

Apart from the phenomenon of holes, it is difficult to find shells showing signs of predation. In the Po River, downstream of Turin, many shells have been found with evident breaks, probably by rats that have eaten them, but in all other collections the shells are almost always whole and intact. Paganelli et al. (2018b) also claim that these bivalves are predated only by few animals, as herons or rats. There are no direct observations on the possible predation by fish or crabs in other continents or European countries, such as in South America (García & Protogino, 2005), by *Silurus glanis* Linnaeus, in France (Vrignaud, 2007) or by *Callinectes sapidus* Rathbun, in Spain (Pla Ventura et al., 2018), but even these possibilities do not seem to be a relevant factor in controlling of clam populations.

Geographic distribution (Fig. 13)

Corbicula fluminalis is scarcely spread in Italy; in lentic water of the largest Pre-Alpine lakes, it has been found frequently only in the lower Lake Garda (Ciutti & Cappelletti, 2009; Ciutti et al., 2011; López-Soriano et al., 2018) and, more recently by the authors, in Lake Iseo. Apart from Lake Garda, where it is quite frequent, in Lake Iseo it seems to be still rare and much localized. The first record of the species from Italy, on 2004 in a small lake near Passo di Lavazè, in Trentino-Alto Adige (Cianfanelli et al., 2007), has not been confirmed on 2019: indeed, because this alpine lake has cold water, is not suitable for the survival of the species. Since the distribution of *Corbicula* species is restricted to not too cold temperatures and moderate altitudes (Gama et al., 2015), it is very difficult that this clam is acclimatized on this site. Therefore, it is possible that the single shell recorded has been occasionally introduced from another locality by tourists, fishermen or fish introduction (in fact, part of this lake is subject to regular introduction of rainbow-trout for sporting fishing). In the year 2019, *C. fluminalis* has been found in another lake of Trentino-Alto Adige (Lake Caldonazzo). Since the Caldonazzo population is mostly composed of young specimens and it is localized in a short stretch of this lake, it is very likely that its origin is rather recent. In lotic water, it has been found only in Mincio River, very downstream of Lake Garda, in the year 2014.

Corbicula fluminea is the most spread species in northern Italy. This species lives throughout the river Po basin and their main tributaries, especially in those of the left hydrographic basin, such as Ticino and Mincio rivers, and in Po River from Turin up to its outfall in the Adriatic Sea. Moreover, it has also invaded the artificial

hydrographic network of the Lombardian and Piedmont plains, such as the irrigation canals of rice crops of the provinces of Vercelli and Novara. More recently, it has spread to the waterways and the artificial network of the Venetian plain, from the Adige River to the Sile River. In the lakes, it is abundant in the lower Lake Garda, in Lake Iseo and in Lake Maggiore. Moreover, in Piedmont, it has also colonized Lake Mergozzo and Lake Viverone. In central Italy, in Tuscany, the presence of this species has not been confirmed in Serchio River, but recently it has been collected in a ditch near the outfall of Serchio River, in Arno River and in its tributary Bisenzio River. *C. fluminea* has been recorded very recently also from Latium, in Maccarese area near Fiumicino and in the Lake Albano near Castel Gandolfo (Grana & Di Giuseppe, 2020).

Corbicula cf. *fluminea* is a taxon distinguishable by virtue of the morphological characters of the shells, but still uncertain in its taxonomic status and undetermined. This taxon is not frequent and has been collected in lower Piedmont and in Lombardy, in Po River and its main left tributaries and in lower Lake Iseo.

Corbicula largillierti is the least frequent species and was known, in Italy, exclusively for Lake Garda, where it has been reported since March 2015 (López-Soriano et al., 2018). This species had been found by the authors near Sirmione (province of Brescia, Lombardy) and near San Benedetto, Peschiera del Garda (province of Verona, Veneto) already on April 2014, although with relatively small specimens (shorter than 14 mm in length). Recent findings, the first in lotic environments, were made in 2019 in the Mincio River and in the final stretch of the Po River, near its outfall.

Corbicula leana was known, in Italy, only from Lake Garda, since 2017 (López-Soriano et al., 2018). In Central-Northern Italy this species is still rather localized and has been found, only since 2018, in Lake Iseo, Lakes of Mantova and in the lower stretches of Ticino and Adda rivers. In Po River, from Ticino River confluence to its overall in the Adriatic Sea, this species is more spread, but not very frequent; it is also spread in some lotic water bodies of Veneto, where it can be locally abundant. In lower trait of Po River, based on our data, the first records are dated 2005, and 2002 in the final stretch of the Adige River, near its outfall. Instead, in Tuscany, it is the most widespread *Corbicula* claim: since 2013 it has been recorded in Serchio River (but erroneously assigned to *C. fluminea*). Indeed, the study of Serchio River shells reveals that the taxon living here is not *C. fluminea*, as previously described by Ercolini & Cenni (2015). The analysis of the shells, collected from 2013 to 2018, and also of new recent samples, reveals that all the specimens must be assigned to *C. leana*. In addition, new populations were observed near San Giuliano Terme (province of Pisa, Tuscany), in water canals, composed of many adult and young shells. It has to be pointed out that the external appearance of these shells resembles to adult specimens of *C. fluminea* (Fig. 8 O-P), although little subtle differences in their global shape can be observed. Even shells from Ticino River resemble

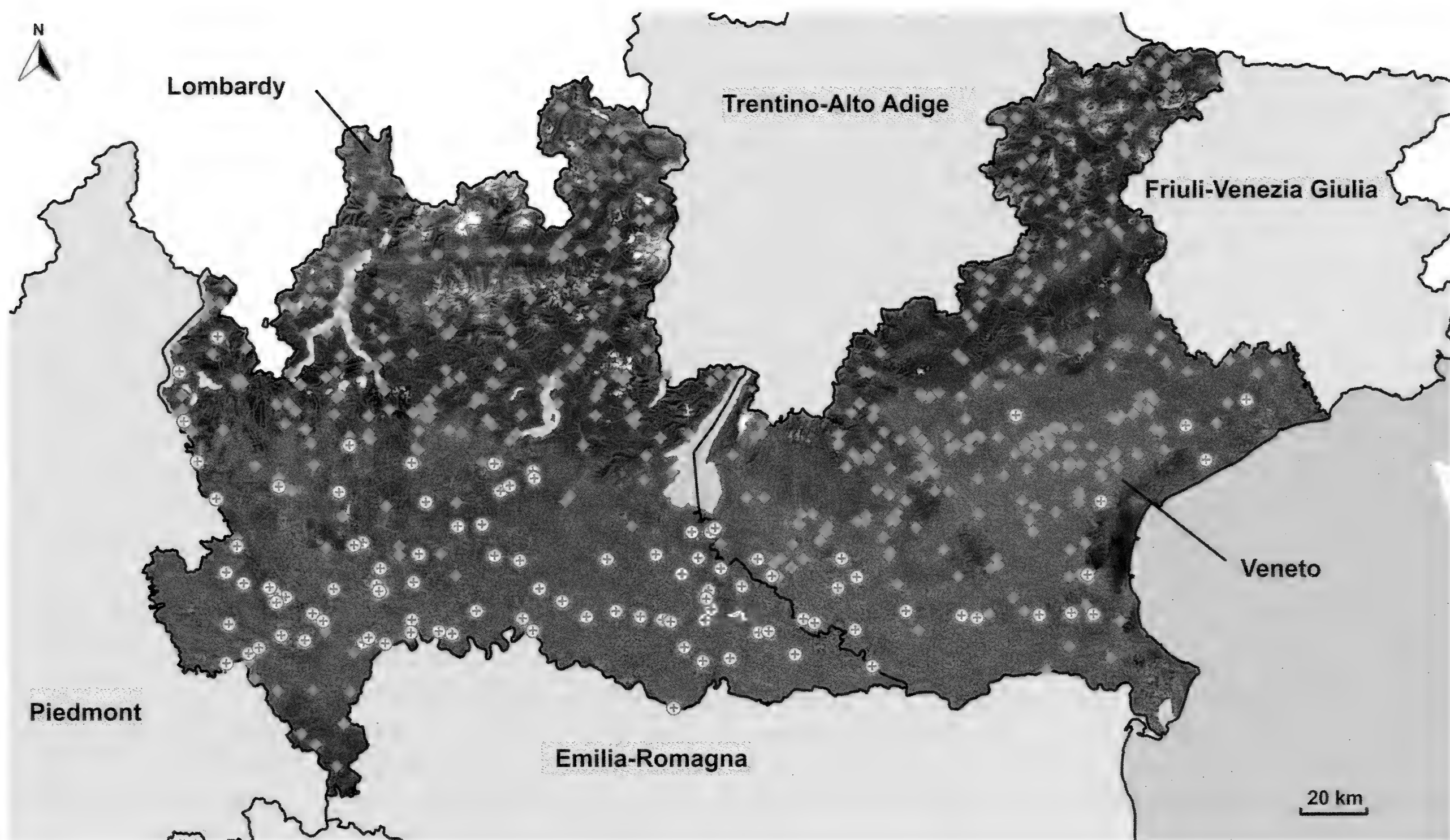


Fig. 12. Geographic distribution of *Corbicula* species in Lombardy and Veneto, on the monitoring river sites of ARPA Lombardia and ARPA Veneto, from 2009 to 2018. Circle with plus: presence; diamond: absence.

Fig. 12. Distribuzione geografica di *Corbicula* spp. in Lombardia e Veneto, sui siti fluviali di monitoraggio dell'ARPA Lombardia e ARPA Veneto, dal 2009 al 2018. Cerchio con il segno più: presenza; rombo: assenza.

C. fluminea, for the lesser H/L ratio (Fig. 8 L). *C. leana* is abundant in the canals near Pisa and also in Bisenzio River, where has been found in recent years. In Bisenzio and Arno rivers it lives syntopically with *C. fluminea*.

Discussion

State of the invasion (Fig. 14)

As known, the possible vectors for *Corbicula* introduction are multiple and their diffusion occurs through different modalities but, in all cases, they always depend on anthropic activities (Karatayev et al., 2007; Lucy et al., 2012; Minchin, 2014). In the United States it seems that the first introductions were caused by eastern migrants, who feed on them (Britton & Morton, 1979; Fox, 1971; Counts, 1981), while in Europe the first reports, in 1980 in the estuary waters of Tago River in Portugal and in the lower Dordogne River in France (Mouthon, 1981), seem to be the result of the release of ballast water discharged by ships coming from North America, containing the pediveliger of these species (Kinzelbach, 1991). However, in France, *Corbicula* was already present in 1976 in Loire River (Hesse et al., 2015), in 1977 in the Dordogne basin (Chevallier, 2000) and since 1980 also in Germany, in Weser River (Haesloop, 1992). In France it seems to have been introduced repeatedly, mainly through the boats in the terminal stretches of the rivers, and from these it has spread upstream and in the adjoining basins, through the canals connecting the different hydrographic systems (Brancotte & Vincent, 2002).

In Northern Italy *Corbicula* has appeared since 1998 in the medium-lower Po basin and the neighbouring water network and, a little later, in the Lake Garda (Fabbri & Landi, 1999; Malavasi et al., 1999; Nardi & Braccia, 2004). The vector used to arrive is not known. It may have been caused by a voluntary introduction as introduced by eastern migrants, who feed on them, or through fish repopulation, carried out with material of the most varied origins; among the possible vectors there is also aquariology, because these species are sold for ornamental purposes (Lois, 2010; Gherardi et al., 2013; Ng et al., 2016). Even the origin of the species in pre-alpine Lake Garda is unknown, but surely related to anthropogenic uses, such as bathers, sporting fishing or tourist and nautical activities, which could have brought the species from distant populations or even other countries not connected with the river basin, mainly Central European countries. After the first introductions, the subsequent diffusion happens quickly; in addition to the natural factors, such as the migration or displacement of the fish species, movement of aquatic birds or other vertebrates and invertebrates, also the human activities constitute a high risk of spreading these species, such as the presence of fishermen and bathers, the inspection and maintenance of river vegetation and embankments, the sediment handling or their monitoring along the watercourses. Among the natural factors, especially the downstream transport by the current facilitates its dispersal and colonization (Lucy et al., 2012).

Since *C. fluminea* has been colonizing European countries for much longer time than other species, it is not a

surprise that it has better chances for colonizing new habitats. Lake Garda is an ideal basin for the arrival and spread of alien species, due to the high tourist vocation and attendance by foreigners: indeed, a multitude of alien organisms have already been ascertained (Ciutti et al., 2011). For example, another non-native bivalve, *Dreissena polymorpha* (Pallas, 1771), appeared in Italy for the first time in 1969 in Lake Garda and, from there, it then

spread to many subalpine lakes and the water network of the lower Po Valley (Franchini, 1980; Cianfanelli et al., 2010; Gherardi et al., 2013). *C. fluminea*, on the other hand, during the early years of its discovery, was already fairly widespread in the lower Po Plain and, therefore, it seems that the arrival may have affected the area of the lower course of the Po River, frequented mainly by boats and fishing activities. Even *C. leana*, re-

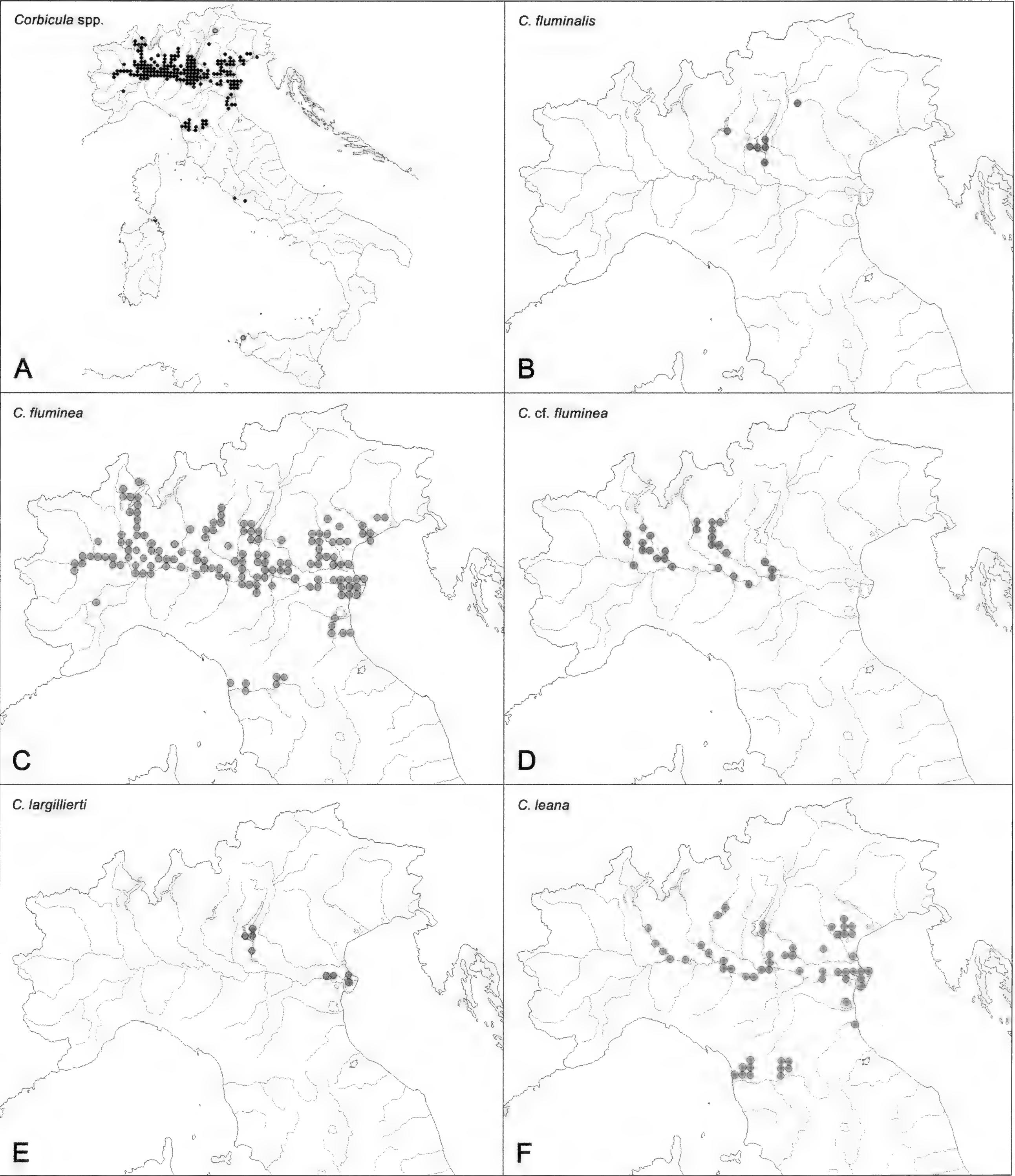


Fig. 13. Geographic distribution of *Corbicula* in Italy, grouped on UTM 10 x 10 km grids, based on literature and studied material. **A.** *Corbicula* genus (black dots: valid data; red dots not-confirmed data); **B.** *C. fluminalis*; **C.** *C. fluminea*; **D.** *C. cf. fluminea*; **E.** *C. largillierti*; **F.** *C. leana*.

Fig. 13. Distribuzione geografica di *Corbicula* in Italia, raggruppata sui quadranti UTM di 10 x 10 km, in base alla letteratura e al materiale studiato. **A.** Genere *Corbicula* (punti neri: dati validi; punti rossi dati non confermati); **B.** *C. fluminalis*; **C.** *C. fluminea*; **D.** *C. cf. fluminea*; **E.** *C. largillierti*; **F.** *C. leana*.

corded in the last section of Adige and Po rivers, may have been introduced in the same way. Differently, it could have happened for other species, such as *C. fluminalis* and *C. largillierti*, whose findings started from Lake Garda and the presence in the watercourses is documented only later and limited to a few other sites. Finally, for *C. cf. fluminea*, present mainly in the lower Lombardy, the introduction could have started from this very anthropized area.

New populations in the Po River were examined, also in its principal tributaries, mostly the rivers of left bank, flowing by major pre-alpine lakes. These populations are composed not only by *C. fluminea* specimens, while in north and western area from Piedmont, in Lake Maggiore as in other smaller pre-alpine lakes (Mergozzo and Viverone), all located in the Po basin, only *C. fluminea* has been found. This fact points towards a preferential way of dispersion of the *Corbicula* species by the river flow, with apparent difficulties to colonize river stretches by dispersion upstream against the river flow. In this sense, a similar situation has been found in the Ebro River, where some *Corbicula* taxa are represented in some tributaries and in the lower part of the river and delta, but not in the main river bed upstream of the junction of some tributaries, where only *C. fluminea* is present (Quiñonero-Salgado & López-Soriano, 2016a). In upper Po river and its hydrographic network, recent sampling upstream Turin, upstream dams, failed to found *Corbicula* clams. In addition, it has to be considered that differential dispersal mechanisms could be acting in different river basins, and the presence of big dams in the Ebro River may impair this type of colonization, while upstream human-mediated or bird-mediated transport (Figuerola & Green, 2002; Schmidlin & Baur, 2007) could play some alternative roles in this directional dispersion.

In Tuscany the presence of *Corbicula*, mainly represented by *C. leana*, is more recent and concerns only the hydrographic networks of the Serchio and Arno rivers. These watercourses are known for the introduction of many alien species, partly due to repopulations with fish material from North Italy, so much so that their bio-coenoses currently present very clear signs of xenobiodiversity (Tricarico et al., 2008; Nocita & Lenuzza, 2016; Cianfanelli et al., 2017; Marrone et al., 2019). Although *Corbicula* has not been observed in local markets, it is an edible mollusc, appreciated and bred in the countries of origin by the eastern communities (Cahn, 1951; Phelps, 1994; Chen et al., 2013). A remarkable Asian community resides in Italy in the provinces of Prato and Florence and the introduction into the watercourses of this area of other edible molluscs, such as *Sinotaia quadrata* (Benson, 1842), currently collected, to sell in the local markets and consumed by these communities, is probably due to this illegal purpose (Cianfanelli et al., 2017).

In the Serchio River (Tuscany) we found only *C. leana*. Re-examination of the specimens previously described as *C. fluminea* (Ercolini & Cenni, 2015) reveals that they all belong to *C. leana*. The presence of abundant populations of only *C. leana* in the irrigation and drainage

canals south of Serchio River (San Giuliano Terme, province of Pisa) confirms a likely fast diffusion of the specie in this plain, as these shells appear to have reached their maximal size of 44 mm in length, even more than the dimensions of the Iberian populations (López-Soriano et al., 2018). In the area of San Giuliano Terme no *Corbicula* has been found in the years 1985-2006. The geographically close Bisenzio and Arno River are also invaded by *Corbicula* species, both *C. leana* and *C. fluminea*, but only recently (from 2016 in Bisenzio River and from 2018 in Arno River). However, the San Giuliano Terme population has arrived there from the Serchio River by a system of artificial canals that interconnect both rivers since centuries ago, so it is likely that the presence of *C. leana* in the lower Arno River may have originated from that of Serchio River. In the Bisenzio River, instead, the introduction of *Corbicula* clams may be caused by a direct immission by Asiatic people, very abundant in this area, because in the first tract of the sector of the Arno River downstream the Bisenzio River, up to Calcinaia (Pisa) no living specimens of *Corbicula* clam has been found but only rare young shells.

Based on our original data, the diffusion in Italy of the species belonging to the genus *Corbicula* is wide and currently occupies almost the entire Padano-Veneto Plain and the plains of Tuscany between Serchio and Arno rivers. The spread of these invasive species has been exponentially increasing in a few years (Fig. 15. A) and, at this time, it is certainly widespread in many other areas, neighbouring to the sampled ones, where full researches are still lacking. Even in Europe, its diffusion is fast (Fig. 15. B). Since 1988, year of the first report, its five-year spread has increased quickly: initially in the lower Po Plain, then in the mainly lakes of Northern Italy and subsequently in the Western Pianura Padana (Fig. 14). For example, until 2008, in the province of Milano *Corbicula* was present only in Ticino River and in the irrigation network tributaries of this waterway (Genoni et al., 2008); currently, in the North-Eastern Lombardy, it is also present in Adda and Lambro rivers and in many artificial canals.

Recently *Corbicula* has also appeared in Tuscany, where it is spreading rapidly. However, its expansion is certainly related to human activities and not to a natural diffusion. Indeed, in non-anthropized environments of North America, it has been observed an upstream movement rate of approximately 1.2 km / year, mainly due to the fish migrations (Voelz et al., 1998). In European rivers, where anthropic factors have certainly interacted, an upstream movement rate of 2.4 km / year in the Elbe River (Beran, 2006) and in the Rhine River (Schmidlin & Baur, 2007) and of 2-22 km / year in French water systems of Loira Basin (Hesse et al., 2015) have been detected. Starting from lower Lombardy, in the central portion of Po River basin near the confluence to the Oglio River (Fabbri & Landi, 1999; Malavasi et al., 1999) and also in the Oglio River (present data), where it was present since the years 1998-1999, *Corbicula* would have risen the river in a few years, up to the

sublacustrin portion of Ticino River on 2003 (Bodon et al., 2005), up to the lower Sesia River on 2012 and up to the Turin portion of the Po river on 2016 (present data). So, counting only the main branch of the river, it would have travelled upstream approximately 250 km in less than 20 years, the distance between Turin and the confluence to Oglio River, therefore with a speed exceeding 12 km / year, clearly too high only in presence of nat-

ural conditions. Considering two elements, such as the presence of the Isola Serafini dam (downstream of Piacenza) and the lack of reports in the years 1983-1994, verified also by the authors through several samplings, the diffusion of *Corbicula* in the upper section of the Po river was certainly due to multiple introductions. In the last few years its presence seems almost extended over the entire diffusion area (Fig. 14. F), but the reports in

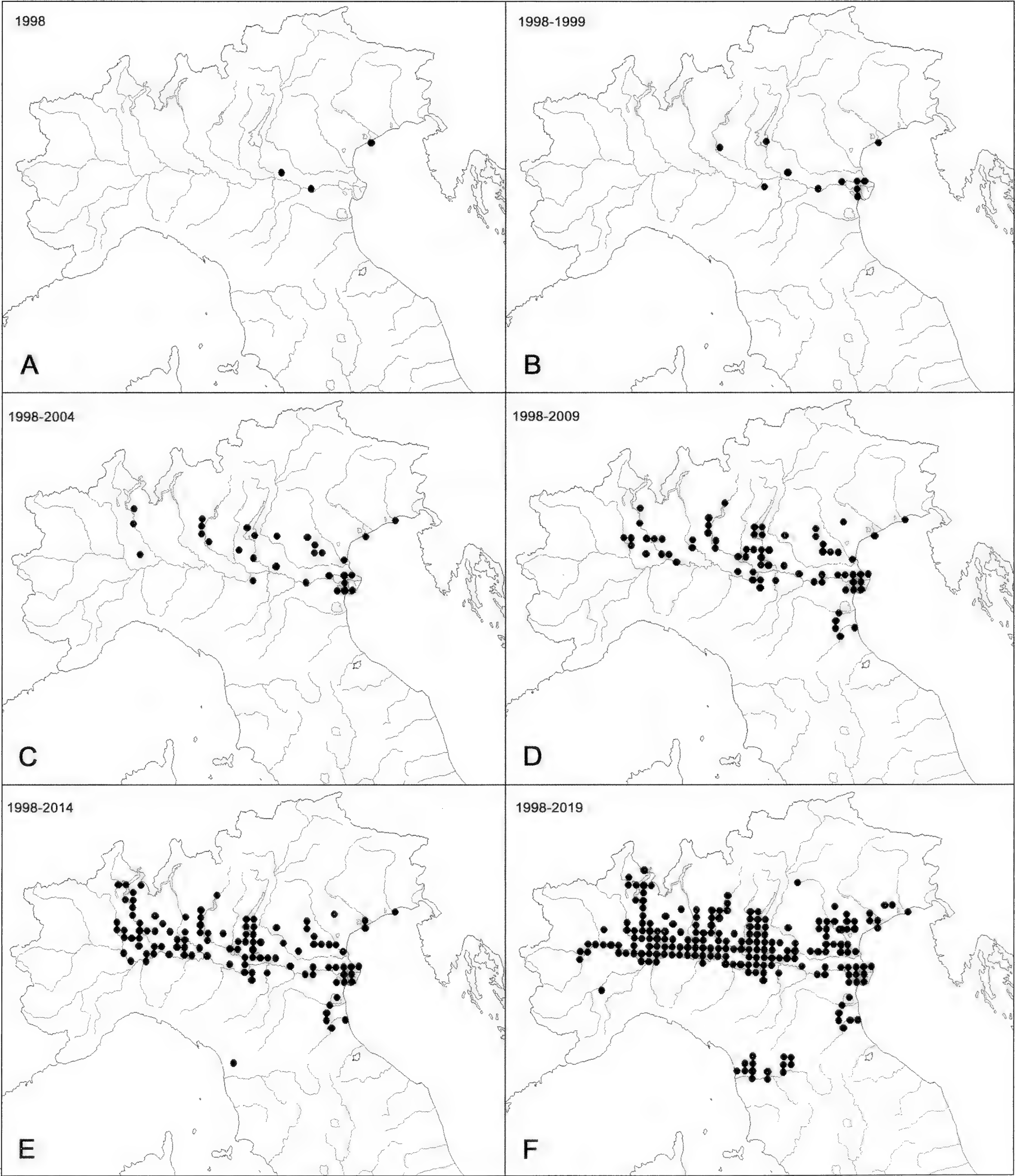


Fig. 14. Chronology of the spread in *Corbicula* species from Italy, grouped on UTM 10 x 10 km grids, based on literature and studied material; cumulative data on five years range. Ranges: **A.** 1998; **B.** 1998-1999; **C.** 1998-2004; **D.** 1998-2009; **E.** 1998-2014; **F.** 1998-2019.

Fig. 14. Cronologia della diffusione delle specie di *Corbicula* in Italia, raggruppata sui quadranti UTM di 10 x 10 km, sulla base della letteratura e del materiale studiato; dati cumulati su cinque anni. Serie: **A.** 1998; **B.** 1998-1999; **C.** 1998-2004; **D.** 1998-2009; **E.** 1998-2014; **F.** 1998-2019.

the recent years are more conspicuous than in past, also due to the present study (Fig. 15. A). Indeed, since the early years of the appearance of these species in Italy, many new studies have been proposed, but always relative to rather limited areas, and a global investigation to verify their spread has been lacking. For instance, by data of ARPA Lombardia, in the regional plain the number of the samples with *Corbicula* is increased from 9,8% to 13,0% in the years from 2009-2013 to 2014-2018, and in the sites where *Corbicula* were in-sediated its average number of specimens is increased from 26 spec/m² to 41 spec/m².

Altogether, our results demonstrate that some populations may hide other *Corbicula* species rather than *C. fluminea* and *C. fluminalis*, as already suggested in different places in North and South America, France, Germany, Spain and in Lake Garda in Italy (Torre & Reyna, 2013; Quiñonero-Salgado & López-Soriano, 2016a; Tiemann et al., 2017; López-Soriano et al., 2018). The syntopic presence of two or more species could indeed be a more widespread situation than expected, since not in-deep analyses have been performed yet in most of the *Corbicula* invasive populations. Our revision of one (Serchio River, Tuscany) previously published Italian lotic population and new researches in North and central Italy confirms this point of view, as it was the case for the Ter and Ebro rivers in Spain (Quiñonero-Salgado & López-Soriano, 2016a; 2016b), or the Rhine in Germany (Nesemann, 2018), where new studies had brought to light taxa not previously cited in those places. Indeed, one of the species present in the Ebro River has been found in public and private collections in samples collected around the year 2000 (Quiñonero-Salgado & López-Soriano, 2016a), thus confirming a cryptic presence for many years, misidentified as *C. fluminea*. In fact, the identification of *C. fluminea* has not followed a true “gold standard” criterion in the last decades, which is also evident because most of the published works do not even include pictures of the collected specimens, and in many cases, citations were only based on few, bad preserved and dead collected specimens, which may not maintain some important diagnostic characters. Even in order to confirm the composition of any *Corbicula* population, a full analysis of each population, including both juveniles and adult specimens, is suggested, including the capture, when available, of live collected specimens, which should always be illustrated in high quality pictures. Additionally, the deposit of some representative specimens of every single population in a public collection is highly recommended, to facilitate the work of future researchers, to either confirm or rebate previous identifications. Detailed comparison with populations of the native range, and molecular confirmations or barcoding of *Corbicula* species will probably have to wait still some years, until new works consider in detail the high diversity and the complex biology of these bivalves. The androgenetic reproductive strategy of these bivalves seems to complicate any interpretation of the mitochondrial molecular analyses used so far, so new

markers (rather nuclear) should be used for a successful barcoding in this group.

Conclusions

After around 80 years of the presence of *Corbicula* in North America, only very recently the paradigm proposed by Morton (1986), of a single invasive freshwater species of *Corbicula* worldwide has been challenged, with the coexistence of more taxa, distinctive both morphologically and genetically, in the very same population (Tiemann et al., 2017). Similarly, at least four species of this genus have been characterized in South America, with *C. largillierti* being almost as widespread as *C. fluminea* (Ituarte, 1994; Torre & Reyna, 2013; Azevêdo et al., 2014; Pereira et al., 2014). The described populations of *Corbicula* in Europe until very recently included only two species, *C. fluminea* and *C. fluminalis* (in sympatry in some areas, including Lake Garda), although molecular and even morphological data already suggested that some cryptic taxa could be present in some river basins (Table 1). Only as recently as 2016, the presence of some other, previously uncharacterized taxa, with the description of some tools to identify them by just characterizing the shell, has been reported in Iberian Peninsula. These include the first European population of *C. largillierti*, and the confirmation of *C. leana* living in sympatry with *C. fluminea* (Quiñonero-Salgado & López-Soriano, 2016a, 2016b). *C. leana* was later confirmed as present in a French population, in a sample previously classified as *C. fluminea*, found in the same river basin (Rhône River) where a distinctive morphotype and haplotype (Rlc) was already described by other authors (Prié, 2017; Quiñonero-Salgado & López-Soriano, 2017b). Similarly, *C. largillierti* has been found in Germany in the Rhine River in sympatry with *C. fluminea* (Nesemann, 2018), altogether showing a general failure in the past in the identification of some *Corbicula* populations in its invasive range. More recently, up to four species have been found in sympatry in Lake Garda, in Northern Italy (López-Soriano et al., 2018).

With all these findings in different continents, countries and river basins, it is not a surprise that some *Corbicula* populations may hide specimens belonging to different species, previously not reported, or even never described as invasive. Notably, *C. leana* is present in Italy in more distant populations from different river basins (Po River and other water bodies in Northern Italy, lower Serchio and Arno basins in Tuscany), which confirm a rather widespread distribution in Western Europe since some years ago, after the previous findings in Spain and France. Indeed, we confirm in this paper the presence of another probable undetermined taxon (*C. cf. fluminea*) not previously cited in Italy.

Beyond the scientific interest, it must be underlined that *Corbicula* clams are highly invasive, competitive and dangerous species for native communities, due to their rapid growth, earlier sexual maturity, short life span and high fecundity (Sousa et al., 2008a). It is hoped that

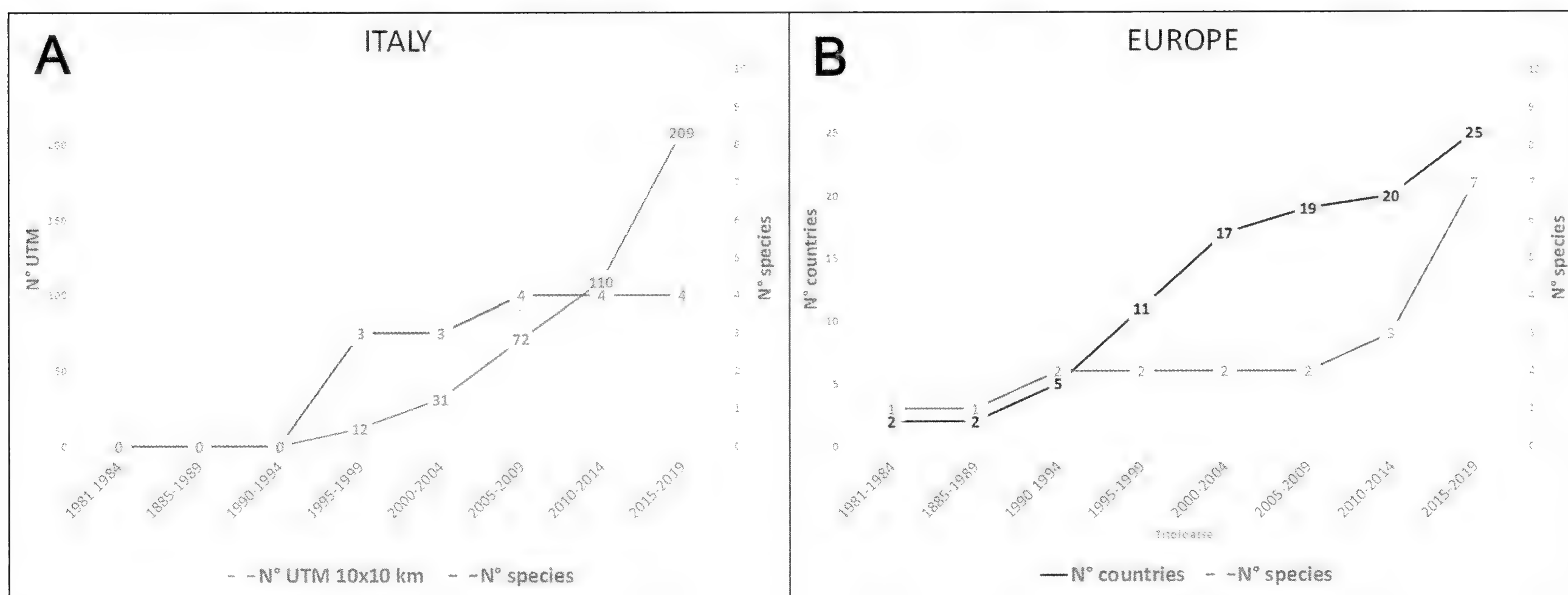


Fig. 15. Chronological trend of spread and number of species for five years ranges in Italy (A) and in Europe (B). **A.** Number of UTM quadrants (10 x 10 km) covered by *Corbicula* spp. on bibliographic data or confirmed by authors, and number of corresponding species; **B.** Number of European countries where bibliographical records of *Corbicula* spp. are reported and total number of species reported in Europe.

Fig. 15. Andamento cronologico della diffusione e numero di specie, cumulati su cinque anni, in Italia (A) e in Europa (B). **A.** Numero di quadranti UTM (10 x 10 km) coperti da *Corbicula* spp. in base ai dati bibliografici o confermati dagli autori, e numero di specie corrispondenti; **B.** Numero di nazioni europee per le quali sono note segnalazioni di *Corbicula* spp. e numero totale di specie riportate in Europa.

rigorous preventive actions will be addressed and implemented to avoid the further spread of these species. In particular, in-depth checks on Asian communities, on internet sales, on preventive actions by visitors to inland. Caffrey et al. (2014, 2016), Minchin (2014) and Coughlan et al. (2019) highlight the need to adopt biosecurity measures on several fronts to contain the spread of these species: Barbour et al. (2013), in example, have used specific disinfectant treatments on the equipment that give the best guarantee to avoid involuntary transport of living specimens. In Lombardy, where the spread of alien species is particularly evident and felt, the Regional Agency for Environmental Protection (AR-PA) equipped itself with a Manual of good practices in environmental monitoring of surface waters (Azzoni, 2014), published on its website. This sampling protocol, for use by its operators, lists some behaviors and sampling procedures to reduce the possibility of transport and introduction of alien species. For example: avoid sampling different watercourses on the same day; proceeding working from upstream to downstream; do not going out on consecutive days; alternate the equipment and tools; cleaning, washing and careful drying the collection equipment and the personal one. In practice, however, this protocol remains difficult to apply, due to the intense rhythm of activities programming.

In Tuscany, the problem of alien species has not been addressed in the context of sampling by the Regional Agency for Environmental Protection (ARPAT), even if the problem is felt by the operators. Above all, there is the problem of their inclusion in the checklists provided by the various methods (diatoms, macrophytes, macrobenthos). Thus, no specific protocols have been developed to prevent their spread. Good practices to contain the spread of exotic species, during the activities of mowing and dredging the canals, carried out by the supervisory authority, were forecasted by Ercolini

(2015) who, taking advantage by his professional experience gained within the “Consorzi di Bonifica”, proposed a good practice to set up an operational protocol that provided for washing and cleaning of mechanical tools, before moving them to other territorial areas. However, his proposal was never accepted and has never been transformed into an operational procedure; furthermore, these types of measures are rarely used during the activities described above. The adoption of this practice could have limited the possible passive transport of larval stages or adult mollusc, but also the spread of fragments and/or cuttings of exotic aquatic plants. On this last topic, it is important to mention the following cases: *Myriophyllum aquaticum* (Vell.) Verdc., reported for the first time in Tuscany by Lastrucci et. al. (2005), initially limited to the Lake Porta (province of Lucca), and now widely spread throughout the Northern Tuscany (unpublished personal data); *Eichornia crassipes* (Mart.) Solms), in Versilia (Ercolini, 2011) and *Alternanthera philoxeroides* (Mart.) Griseb., in the Florence section of Arno River (Cimoli & Magi, 2009).

It is clear that these rules can be adopted only if all the interested parties will show an adequate sensitivity and maturity. Unfortunately, due to the extraordinary prolificacy of these species, the very small size of the first free-living stages (the pediveliger have a diameter of only 0.2 mm) and the possibility that young clams being distributed by means of a byssal dragline flotation and adhesion by mucous strands, secreted in response to water current stimuli (Prezant & Chalermwat, 1984a; Minchin, 2014; Minchin & Boelers, 2018), make it very difficult to safeguard environments that are still free from contamination. However, in the areas already invaded, currently severe repression interventions (e.g. prohibition of collection and detention) would by now be completely useless and even harmful. In any case, if now in some places it could be a resource, failure to

exploit it does not allow to have populations under control.

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Appendix

LIST OF LOCALITIES AND EXAMINED MATERIAL

PIEDMONT

Po River basin

- Po River, Michelotti dam, Murazzi, Turin, 220 m a.s.l. (Torino, TO), 32T LQ9791, C. Rossato leg. 11/08/2016, FLU (1 sh, SBC).
- Po River downstream the bridge between Gassino Torinese and Settimo Torinese, 195 m a.s.l. (Gassino Torinese, TO), 32T MQ0498, M. Bodon & G. Vezzani leg. 02/03/2019, FLU (25 sh, 17 juv sh, MBC).
- Po River upstream the new bridge north-west of Piana San Raffaele, 183 m a.s.l. (Gassino Torinese, TO), 32T MR0800, M. Bodon & G. Vezzani leg. 02/03/2019, FLU (2 juv sh, MBC).
- Po River downstream the new bridge north-west of Piana San Raffaele, 182 m a.s.l. (San Raffaele Cimentina, TO), 32T MR0801, M. Bodon & G. Vezzani leg. 02/03/2019, FLU (3 sh, MBC).
- Po River, locality Porto di San Sebastiano, 165 m a.s.l. (San Sebastiano da Po, TO), 32T MR1602, M. Bodon & G. Vezzani leg. 26/01/2019, FLU (2 sh, 4 juv sh, MBC).
- Po River at the bridge south of Crescentino, near the castle of Verrua, 150 m a.s.l. (Verrua Savoia, TO), 32T MR2903, M. Bodon leg. 26/01/2019, FLU (4 juv sh, MBC).
- Po River south of Palazzolo Vercellese, 130 m a.s.l. (Palazzolo Vercellese, VC), 32T MR4002, M. Bodon

& G. Vezzani leg. 22/12/2018, FLU (3 juv sh, MBC).

- Po River at the bridge downstream Pontestura, 118 m a.s.l. (Pontestura, AL), 32T MQ4899, M. Bodon leg. 26/03/2019, FLU (5 sh, MBC).
- Po River 1 km upstream Casale Monferrato, 106 m a.s.l. (Casale Monferrato, AL), 32T MQ5598, M. Bodon leg. 08/12/2018, FLU (2 sh, 5 juv sh, MBC).
- Po River 1 km south-west of Terranova, 96 m a.s.l. (Casale Monferrato, AL), 32T MR6100, M. Bodon leg. 08/12/2018, FLU (58 juv sh, MBC).
- Po River 2 km downstream Bozzole, 90 m a.s.l. (Bozzole, AL), 32T MQ7090, M. Bodon leg. 25/11/2018, FLU (86 juv sh, MBC).
- Po River just downstream of the Valenza bridge, 84 m a.s.l. (Valenza, AL), 32T MQ7188, M. Bodon & G. Vezzani leg. 14/10/2017, FLU (7 sh, 15 juv sh, 1 juv sp, MBC).
- Po River upstream Bassignana, 80 m a.s.l. (Bassignana, AL), 32T MQ7883, M. Bodon & G. Vezzani leg. 18/11/2018, FLU (4 juv sh, MBC).
- Po River north of Bassignana, 78 m a.s.l. (Bassignana, AL), 32T MQ7983, M. Bodon & G. Vezzani leg. 18/11/2018, FLU (34 juv sh, MBC).
- Po River, locality Deserto, 900 m downstream the bridge on the road between Guazzora and Pieve di Cairo, Isola Sant'Antonio, 70 m a.s.l. (Isola Sant'Antonio, AL), 32T MQ8687, M. Bodon & G. Vezzani leg. 18/11/2018, FLU (41 juv sh, MBC).

Po River basin - Dora Baltea River sub-basin

- Lake Viverone, south-western bank, west of Cascina Nuova, 230 m a.s.l. (Viverone, BI), 32T MR2328, M. Bodon & G. Vezzani leg. 29/07/2017, FLU (18 sh, MZUF BC/60335; 3 sh, 11 juv sh, 1 sp, MBC; 5 sp, JLC).

Po River basin - Sesia River sub-basin

- Ditch 200 m west of Santuario della Madonna della Prieria, west of Biandrate, 155 m a.s.l. (Biandrate, NO), 32T MR5732, M. Bodon & G. Vezzani leg. 01/04/2017, CLU (3 sh, 1 juv sp, MBC).
- Irrigation ditch among the rice-fields 1 km west of Biandrate, 155 m a.s.l. (Biandrate, NO), 32T MR5732, M. Bodon & E. Bodon leg. 13/10/2013, FLU (8 juv sh, MBC).
- Crosio Ditch near the Santuario della Madonna della Prieria, west of Biandrate, 154 m a.s.l. (Biandrate, NO), 32T MR5732, M. Bodon & G. Vezzani leg. 01/04/2017, FLU (1 sh, MBC), CLU (2 sh, 6 juv sh, 2 juv sp, MBC), M. Bodon & G. Vezzani leg. 27/05/2019, FLU (19 sh, 15 juv sh, 11 sp, 10 juv sp, MBC; 8 sp, 12 juv sp, INC), CLU (2 juv sp, MZUF BC/60336; 19 sh, 3 juv sh, 2 sp, MBC; 3 sp, INC).
- Ladro Ditch south-east of Cascina Stroppera, Ponzana, 142 m a.s.l. (Casalino, NO), 32T MR6129, M. Bodon & E. Bodon leg. 25/04/2006, FLU (11 sh, MBC).
- Bolgora irrigation Canal north of Borgo Vercelli, 125 m a.s.l. (Borgo Vercelli, VC), 32T MR5823, M. Bodon & G. Vezzani leg. 01/04/2017, CLU (3 sh, MBC).

- Sesia River, locality Torrette, Passo di Frassineto Po, 97 m a.s.l. (Frassineto Po, AL), 32T MQ6499, P. Palazzolo leg. 25/11/2012, CLU (1 sh), L. Gola leg. 03/12/2012, CLU (5 sh).

Po River basin - Tanaro River sub-basin

- Verduno Canal east-north-east of Casa Gamba di Bosco, Borgo Piave, Alba, 165 m a.s.l. (Alba, CN), 32T MQ2149, M. Bodon & G. Vezzani leg. 23/02/2019, FLU (1 juv sh, 4 juv sp, MBC).

Po River basin - Agogna Stream sub-basin

- Irrigation ditch 100 m east-north-east of Cascina San Dionigi, on the road between Borgo Lavezzaro and Cascinino dell'Agogna, Chiusa di Nicorvo, 120 m a.s.l. (Borgolavezzaro, NO), 32T MR7518, G. Mortarino leg. 09/09/2014, CLU (5 sp).

Po River basin - Terdoppio Stream sub-basin

- Barbavara irrigation Ditch, 500 m north-east of the cemetery of Tornaco, 120 m a.s.l. (Tornaco, NO), 32T MR7823, L. Mostini leg. 15/03/2016, CLU (1 sh).

Po River basin - Ticino River sub-basin

- Lake Mergozzo, north side of the port of Mergozzo, 196 m a.s.l. (Mergozzo, VB), 32T MR5790, M. Bodon & G. Vezzani leg. 21/07/2018, FLU (50 sh).
- Lake Mergozzo, south side of the port of Mergozzo, 196 m a.s.l. (Mergozzo, VB), 32T MR5789, M. Bodon & G. Vezzani leg. 21/07/2018, FLU (500 sh).
- Lake Mergozzo just east of Mergozzo, 196 m a.s.l. (Mergozzo, VB), 32T MR5790, M. Bodon & G. Vezzani leg. 21/07/2018, FLU (3 juv sh, MBC).
- Lake Mergozzo off the southern shore, 196 m a.s.l. (Mergozzo, VB), 32T MR5988, M. Bodon leg. 29/08/2014, FLU (1 juv sp, MBC).
- Lake Mergozzo, southern shore, locality Il Portaiolo, 196 m a.s.l. (Mergozzo, VB), 32T MR5988, M. Bodon & G. Vezzani leg. 29/08/2014, FLU (3 juv sp, MBC), M. Bodon & G. Vezzani leg. 26/06/2017, FLU (9 sh, MZUF BC/62199; 22 sh, 55 juv sh, 3 sp, 110 juv sp, MBC; 3 sp, JLC), M. Bodon & G. Vezzani leg. 19/07/2018, FLU (10 sh, MZUF BC/62200; 11 sh, 17 juv sh, 3 sp, 47 juv sp, MBC; 2 sp, 8 juv sp, MZUF BC/59025), M. Bodon & G. Vezzani leg. 30/06/2019, FLU (4 sp, 2 juv sp, MZUF BC/60337; 43 sh, 28 juv sh, 2 juv sp, MBC; 4 sp, 1 juv sp, INC).
- Lake Maggiore, small beach near the port north of Cannobio, 193 m a.s.l. (Cannobio, VB), 32T MS7601, M. Bodon & G. Vezzani leg. 24/07/2018, FLU (16 juv sh, MBC).
- Lake Maggiore south of Ghiffa, 193 m a.s.l. (Ghiffa, VB), 32T MR7089, M. Bodon & G. Vezzani leg. 24/07/2018, FLU (1 juv sh, MBC).
- Lake Maggiore, 2 km east of Fondotoce, small beach at end of the Fondotoce reed bed, 193 m a.s.l. (Verbania, VB), 32T MR6287, M. Bodon & G. Vezzani leg. 26/06/2017, FLU (6 sh, 14 juv sh, MBC).
- Lake Maggiore north of Feriolo, near the Camping Orchidea, 193 m a.s.l. (Baveno, VB), 32T MR6086, M.

- Bodon & G. Vezzani leg. 28/06/2013, FLU (16 sh, 21 juv sh, MBC), M. Bodon & G. Vezzani leg. 20/07/2018, FLU (20 sh, MZUF BC/62201; 4 sh, 16 juv sh, MBC; 10 sp).
- Lake Maggiore, Feriolo, 193 m a.s.l. (Baveno, VB), 32T MR5986, M. Bodon & G. Vezzani leg. 28/06/2013, FLU (17 sh, 3 juv sh, MBC).
 - Lake Maggiore, Isola dei Pescatori, northern tip, eastern shore, 193 m a.s.l. (Stresa, VB), 32T MR6283, M. Bodon & G. Vezzani leg. 28/08/2014, FLU (1 sh).
 - Lake Maggiore, Isola dei Pescatori, northern tip, western shore, 193 m a.s.l. (Stresa, VB), 32T MR6283, M. Bodon & G. Vezzani leg. 28/08/2014, FLU (5 sh, 3 juv sh, MBC).
 - Lake Maggiore near the Mottarone cableway station, Stresa, 193 m a.s.l. (Stresa, VB), 32T MR6382, M. Bodon & G. Vezzani leg. 20/07/2018, FLU (2 sh).
 - Lake Maggiore south-east of the port of Arona, north of Vevera Stream mouth, 193 m a.s.l. (Arona, NO), 32T MR6667, M. Bodon & G. Vezzani leg. 18/07/2013, FLU (23 sh, 1 juv sh, MBC).
 - Lake Maggiore south of the port of Arona, 193 m a.s.l. (Comignago, NO), 32T MR6666, M. Bodon & G. Vezzani leg. 28/08/2014, FLU (3 sh, MBC).
 - Ticino River, Castelletto Sopra Ticino, 193 m a.s.l. (Castelletto Sopra Ticino, NO), 32T MR7163, M. Bodon & E. Bodon leg. 27/04/2003, FLU (17 sh, 2 juv sh, MBC; 1 sp).
 - Ticino River, Cascina Belvedere, upstream the dam, 184 m a.s.l. (Varallo Pombia, NO), 32T MR7558, M. Bodon & E. Bodon leg. 11/09/2010, FLU (6 sh, 17 juv sh, 1 sp, 20 juv sp, MBC).
 - Ticino River just upstream the motorway viaduct Milan-Turin, 115 m a.s.l. (Romentino, NO), 32T MR8335, M. Costa & S. Costa leg. 14/10/2011, LEA (1 juv sp, MBC), M. Costa & S. Costa leg. 09/12/2012, CLU (1 sp, 1 juv sp, MBC), M. Costa & S. Costa leg. 15/03/2013, FLU (3 juv sp, MBC), M. Costa & S. Costa leg. 05/06/2013, FLU (1 juv sp, MBC).
 - Ticino River 100 m downstream the motorway viaduct Milan-Turin and the railway viaduct, 115 m a.s.l. (Romentino, NO), 32T MR8335, M. Costa & S. Costa leg. 09/11/2012, CLU (2 sp, MBC).
 - Langosco Canal, Vizzola hydroelectric station, Galliate, 130 m a.s.l. (Galliate, NO), 32T MR7740, M. Bodon & E. Bodon leg. 11/10/2003, FLU (1 sh, MBC).
 - Langosco Canal, locality Ponte Ticino, Galliate, 128 m a.s.l. (Galliate, NO), 32T MR7839, M. Bodon & G. Vezzani leg. 01/12/2018, FLU (2 sp, MZUF BC/60338; 45 sh, 8 juv sh, 2 sp, MBC), CLU (15 sh, 6 juv sh, 2 sp, MBC).
 - (Mezzana Bigli, PV), 32T MQ9490, M. Bodon leg. 16/11/2018, FLU (1 sh, 1 juv sh, MBC).
 - Po River 1,5 km downstream the join with Agogna Stream, downstream the Gerola Bridge, 60 m a.s.l. (Sannazzaro de' Burgondi, PV), 32T MQ9490, M. Bodon leg. 16/11/2018, FLU (36 juv sh, MBC).
 - Po River near Tornello, downstream the Becca Bridge, 55 m a.s.l. (Albaredo Arnaboldi, PV), 32T NQ1898, M. Bodon leg. 21/10/2018, FLU (3 sh, 6 juv sh, MBC), LEA (1 sh, MBC).
 - Po River, 0,6 km upstream the Mezzano Bridge, 50 m a.s.l. (Pieve Porto Morone, PV), 32T NQ3493, M. Bodon leg. 28/02/2019, FLU (2 sh, MZUF BC/60339; 45 sh, 7 juv sh, MBC), LEA (4 sh, MBC).
 - Po River, bridge of Mezzano, 50 m a.s.l. (Pieve Porto Morone, PV), 32T NQ3593, M. Bodon leg. 28/02/2019, FLU (31 sh, 6 juv sh, MBC), LEA (3 sh, 1 juv sh, MBC).
 - Po River, Viale Lungo Po Europa below the bridge on the provincial road 10, south-west of Cremona, 38 m a.s.l. (Cremona, CR), 32T NQ7897, G. Nardi leg. 16/09/2018, FLU (6 sh, 2 juv sh, GNC).
 - Po River west of Cascina Bosconello, Cremona, 30 m a.s.l. (Cremona, CR), 32T NQ7995, G. Nardi leg. 16/03/2019, FLU (33 sh, 4 juv sh, GNC), CLU (2 sh, 1 juv sh, GNC).
 - Po River west of Stagno Lombardo, 30 m a.s.l. (Stagno Lombardo, CR), 32T NQ8291, G. Nardi leg. 16/03/2019, FLU (3 sh, 1 juv sh, GNC), LEA (1 juv sh, GNC).
 - Po River, Casalmaggiore, Parco della Golena del Po, 25 m a.s.l. (Casalmaggiore, CR), 32T PQ1182, G. Nardi leg. 16/09/2018, FLU (1 sh, GNC).
 - Po River below the bridge on the provincial road 358, south-east of Viadana, 20 m a.s.l. (Viadana, MN), 32T PQ2174, G. Nardi leg. 16/09/2018, FLU (13 sh, GNC), LEA (1 juv sh, GNC).
 - Po River, San Martino, south-west of Viadana, 20 m a.s.l. (Viadana, MN), 32T PQ1974, M. Bodon & G. Nardi leg. 16/03/2019, FLU (9 sh, 2 juv sh, MBC), LEA (3 sh, 9 juv sh, MBC), CLU (2 sh, 5 juv sh, MBC).
 - Po River north of Portiolo, 15 m a.s.l. (San Benedetto Po, MN), 32T PQ4690, M. Bodon leg. 17/03/2019, FLU (8 sh, 12 juv sh, MBC), LEA (1 juv sh, MBC), CLU (2 sh, 4 juv sh, MBC).
 - Po River north of Villa Saviola, 15 m a.s.l. (Motteggiana, MN), 32T PQ4189, M. Bodon & G. Nardi leg. 17/03/2019, FLU (26 sh, 31 juv sh, MBC), LEA (2 juv sh, MBC), CLU (1 sh, MBC).
 - Po River downstream the bridge of Borgoforte, 15 m a.s.l. (Motteggiana, MN), 32T PQ3989, M. Bodon & G. Nardi leg. 17/03/2019, FLU (18 sh, 16 juv sh, MBC), LEA (18 sh, 10 juv sh, MBC).
 - Po River upstream del bridge of San Benedetto Po, Bianchina, 15 m a.s.l. (San Benedetto Po, MN), 32T PQ5193, M. Bodon leg. 19/04/2014, FLU (6 sh, MBC).
 - Po River near the Lauro Zampolli touristic port, downstream the bridge of San Benedetto Po, 15 m

LOMBARDY

Po River basin

- Po River, 500 m downstream the Gerola Bridge, 65 m a.s.l. (Mezzana Bigli, PV), 32T MQ9289, M. Bodon leg. 16/11/2018, FLU (58 juv sh, MBC).
- Po River 1 km downstream the join with Agogna Stream, downstream the Gerola Bridge, 60 m a.s.l.

a.s.l. (Bagnolo San Vito, MN), 32T PQ5293, M. Bodon leg. 19/04/2014, FLU (1 sh, 3 juv sh, MBC).

- Melotta Waterway, Melotta, 85 m a.s.l. (Casaletto di Sopra, CR), 32T NR6329, A. Busetto leg. 01/05/2011, CLU (2 sh, GNC).
- Irrigation ditches 1 km south of Alperolo, 75 m a.s.l. (Albuzzano, PV), 32T NR2002, M. Bodon leg. 06/07/2019, FLU (6 sh, 1 juv sh, MBC).

Po River basin - Agogna Stream sub-basin

- Ditch behind the cemetery of Nicorvo, 110 m a.s.l. (Nicorvo, PV), 33T MR7315, L. Mostini leg. 11/02/2017, FLU (6 sh).
- Confienzo Canal, Confienza, 120 m a.s.l. (Confienza, PV), 32T MR6619, G. Lazarotto leg. 13/02/2007, FLU (4 sh, INC).

Po River basin - Terdoppio Stream sub-basin

- Terdoppio Stream at the bridge of the road toward Remondò, south-west of Gambolò, 100 m a.s.l. (Gambolò, PV), 32T MR8814, M. Bodon & G. Vezzani leg. 08/12/2018, CLU (16 sh, 4 juv sh, 1 sp, 1 juv sp, MBC).

Po River basin - Ticino River sub-basin

- Lake Maggiore along Viale P. Martire, 500 m north of Piazza Vittoria, Angera, 193 m a.s.l. (Angera, VA), 32T MR6669, I. Niero leg. 30/07/2010, FLU (2 sh, INC).
- Ticino River just upstream the join with the hydro-electric station canal, north of Vigevano, 85 m a.s.l. (Vigevano, PV), 32T MR9021, M. Bodon & G. Vezzani leg. 09/12/2018, FLU (2 juv sh, MBC).
- Ticino River 1,5 km upstream the bridge of Bereguardo, 70 m a.s.l. (Zerbolò, PV), 32T MR9910, M. Bodon & G. Vezzani leg. 29/09/2018, FLU (5 sp, 3 juv sp, MZUF BC/60340; 13 juv sp, MBC), LEA (1 sp, 1 juv sp, MZUF BC/60341).
- Ticino River 1 km upstream the bridge of Bereguardo, 70 m a.s.l. (Bereguardo, PV), 32T NR0009, M. Bodon & G. Vezzani leg. 29/09/2018, FLU (15 sh, MZUF BC/61202; 30 sh, 7 juv sh, MBC), LEA (4 sh, MZUF BC/61203).
- Ticino River 500 m upstream the bridge of Bereguardo, 70 m a.s.l. (Bereguardo, PV), 32T NR0009, M. Bodon & G. Vezzani leg. 08/06/2019, FLU (21 sh, 21 juv sh, MBC), CLU (1 sh, MBC), FLU (42 sh, 22 juv sh, 2 juv sp, MBC), CLU (6 sh, 1 juv sh, MBC), LEA (5 sh, 1 juv sh, MBC).
- Ticino River downstream Cascina Oltrona, San Leonardo, 55 m a.s.l. (Valle Salimbene, PV), 32T NR1700, M. Bodon leg. 25/10/2018, FLU (1 juv sp, MBC).
- Ticino River upstream the Bridge della Becca, 55 m a.s.l. (Linarolo, PV), 32T NQ1799, M. Bodon leg. 25/10/2018, FLU (39 sh, 9 juv sh, 1 sp, 36 juv sp, MBC), LEA (12 sh, MBC), M. Bodon leg. 06/07/2019, FLU (20 sh, ARPA-L; 97 sh, 15 juv sh, 2 sp, 1 juv sp, MBC; 3 sp, INC), CLU (14 sh, 6 juv sh, MBC), LEA (7 sh, MZUF BC/62204; 1 juv sh, MBC).

- Ticino River, Bridge della Becca, 55 m a.s.l. (Linarolo, PV), 32T NQ1799, M. Bodon & G. Vezzani leg. 20/10/2019, FLU (76 sh, 3 juv sh, MBC), LEA (5 sh, MZUF BC/62205; 6 sh, 1 juv sh, MBC).
- Oxbow of Ticino River, Osteria della Becca downstream the Bridge della Becca, 60 m a.s.l. (Linarolo, PV), 32T NQ1899, M. Bodon leg. 06/07/2019, FLU (1 sh, MBC).
- Vecchio Waterway, Tubigaccio, 140 m a.s.l. (Lonate Pozzolo, VA), 32T MR7746, A. Dal Mas & A. Fazzzone leg. 14/11/2018, CLU (4 sh, 35 sp, 4 juv sp, MBC, MZUF BC/59056).
- Marinone Canal, Tubigaccio, 140 m a.s.l. (Lonate Pozzolo, VA), 32T MR7746, E. Lorenzi leg. 31/01/2013, FLU (4 sp, ARPA-L, MZUF BC/59024), CLU (20 sp., ARPA-L; 1 sh, 25 sp, MBC, MZUF BC/59055).
- Marinone Canal, south-west of Nosate, 135 m a.s.l. (Nosate, MI), 32T MR7744, E. Lorenzi leg. 31/01/2013, FLU (2 sp, MBC, MZUF BC/59021), CLU (20 sp, MZUF BC/59053; 1 sh, 23 sp, MBC, MZUF BC/59053).
- Grande Waterway, Castelletto di Cuggiono, 130 m a.s.l. (Cuggiono, MI), 32T MR8338, A. Dal Mas & A. Fazzzone leg. 14/11/2018, CLU (12 sh, 8 sp, MZUF BC/59052; 15 sh, 23 juv sh, 101 juv sp, MBC, MZUF BC/59052).
- Alluvial spring at Via Matteotti, just south of Bernate Ticino, downstream the motorway Milan-Turin, 125 m a.s.l. (Bernate Ticino, MI), 32T MR8535, M. Costa & S. Costa leg. 13/03/2013, FLU (2 juv sp, MBC, MZUF BC/59020).
- Ripa alluvial spring, south-west of Bernate Ticino, upstream the motorway Milan-Turin, 120 m a.s.l. (Bernate Ticino, MI), 32T MR8435, M. Costa & S. Costa leg. 18/10/2011, FLU (4 juv sp, MBC), M. Costa & S. Costa leg. 13/03/2013, FLU (1 sp, 3 juv sp, MBC).
- Ripa alluvial spring, south-west of Bernate Ticino, downstream the motorway Milan-Turin, 120 m a.s.l. (Bernate Ticino, MI), 32T MR8435, M. Costa & S. Costa leg. 13/03/2013, FLU (1 sp, MBC).
- Ditch at the beginning of the road toward Cascina Fornasetta, 700 m west-north-west of Bereguardo, 95 m a.s.l. (Bereguardo, PV), 32T NR0111, M. Bodon & G. Vezzani leg. 08/06/2019, FLU (2 sh, 1 juv sh, MBC), CLU (2 sh, 3 juv sh, MBC).
- Nuovo Ditch, east of an abandoned farmstead 1,3 km north-east of Parasacco, 70 m a.s.l. (Zerbolò, PV), 32T MR9909, M. Bodon & G. Vezzani leg. 29/09/2018, CLU (5 sh, 1 juv sh, 1 sp, MBC).
- Baldasserina Ditch, 1 km upstream the bridge of Bereguardo, 70 m a.s.l. (Zerbolò, PV), 32T MR9909, M. Bodon & G. Vezzani leg. 29/09/2019, CLU (6 sh, 4 juv sh, 7 sp, 14 juv sp, MBC).
- Baldasserina Ditch near the mouthing into Ticino River, 400 m upstream the bridge of Bereguardo, 70 m a.s.l. (Zerbolò, PV), 32T NR0009, M. Bodon & G. Vezzani leg. 29/09/2019, FLU (4 sh, 1 juv sh, 7 sp, 1 juv sp, MBC), CLU 81 sh, MBC).

- Gravellone Ditch, Chiavica del Gravelone, 60 m a.s.l. (Travacò Siccomario, PV), 32T NR1202, N. Pizzochero & M. Marchesi leg. 17/09/2018, FLU (3 sp, MBC), N. Pizzochero & M. Marchesi leg. 20/02/2018, FLU (1 juv sp, MBC, MZUF BC/59023).

Po River basin - Lambro River sub-basin

- Lambro River, old bridge on the ex-state road 235, locality La Motta, Sant'Angelo Lodigiano, 65 m a.s.l. (Sant'Angelo Lodigiano, LO), 32T NR3210, N. Pizzochero & M. Marchesi leg. 28/03/2018, FLU (1 sp, MBC, MZUF BC/59019).
- Addetta Ditch, state road Vecchia Cerca, 85 m a.s.l. (Vizzolo Predabissi, MI), 32T NR2624, F. Elvio leg. 04/10/2017, FLU (1 sp, 2 juv sp, MBC).

Po River basin - Adda River sub-basin

- Adda River near the Santuario della Divina Maternità, Trezzo sull'Adda, 135 m a.s.l. (Trezzo sull'Adda, MI), 32T NR4150, M. Bodon, G. Nardi & G. Vezzani leg. 24/08/2019, CLU (5 sh, 1 sp, MBC).
- Adda River 1,2 km south of the Santuario della Divina Maternità, Trezzo sull'Adda, 130 m a.s.l. (Vaprio d'Adda, MI), 32T NR4148, A. Dal Mas leg. 16/09/2015, CLU (1 sp, MBC), A. Dal Mas & F. Elvio leg. 25/02/2016, CLU (1 juv sh, ARPA-L), A. Dal Mas leg. 14/11/2018, CLU (4 sh, 7 juv sh, 17 sp, 43 juv sp, MBC, MZUF BC/59054; 2 sh, 1 sp, 3 juv sp, INC), M. Bodon, G. Nardi, A. Dal Mas & G. Vezzani leg. 24/08/2019, FLU (2 sp, 4 juv sp, MBC; 2 sh, GNC; 1 sp, INC), CLU (2 sp, 2 juv sp, MZUF BC/60342; 12 sh, 10 sp, 7 juv sp, MBC; 14 sh, 2 juv sh, 11 sp, GNC; 4 sp, INC).
- Adda River downstream the bridge between Castelleone and Castiglione d'Adda, west of Gombito, 46 m a.s.l. (Ripalta Arpina, CR), 32T NR5512, M. Bodon, G. Nardi & A. Braccia leg. 13/10/2018, FLU (12 sh, 18 juv sh, MBC), LEA (4 juv sh, MBC).
- Adda River 800 m south of Cascina Fasola, at the mouth of Fossadone irrigation Ditch, west-north-west of Formigara, 45 m a.s.l. (Formigara, CR), 32T NR5708, M. Bodon, G. Nardi & A. Braccia leg. 13/10/2018, FLU (3 juv sp, MBC).
- Adda River 350 m upstream del bridge of Crotta d'Adda, 35 m a.s.l. (Maccastorna, LO), 32T NR6601, M. Bodon, G. Nardi & A. Braccia leg. 13/10/2018, FLU (10 sh, MZUF BC/62206; 18 sh, 10 juv sh, MBC).
- Adda River 300 m upstream the bridge of Crotta d'Adda, 35 m a.s.l. (Maccastorna, LO), 32T NR6701, A. Braccia leg. 16/07/2017, FLU (5 sh, ABC; 1 sh, GNC), M. Bodon, G. Nardi & A. Braccia leg. 13/10/2018, FLU (8 sh, 2 sp, MZUF BC/60343; 10 juv sh, 40 juv sp, MBC), LEA (1 sh, 1 juv sh, MBC).
- Adda River 300 m upstream the join with Po River, 34 m a.s.l. (Maccastorna, LO), 32T NQ6998, M. Bodon, G. Nardi & A. Braccia leg. 13/10/2018, FLU (1 sh, 3 juv sh, MBC).
- Fossadone irrigation Ditch, 450 m east of Cascina Fasolina, west-north-west of Formigara, 45 m a.s.l. (Formigara, CR), 32T NR5709, M. Bodon, G. Nardi &

A. Braccia leg. 13/10/2018, FLU (2 sp, MZUF BC/60344; 3 sh, 9 sp, 1 juv sp, MBC).

Po River basin - Oglio River sub-basin

- Lake Iseo, locality Pero, Sulzano, 185 m a.s.l. (Sale Marasino, BS), 32T NR8661, M. Bodon & G. Vezzani leg. 21/08/2018, FLU (19 sh, 66 juv sh, MBC), LEA (1 sh, MBC).
- Lake Iseo, Iseo, 185 m a.s.l. (Iseo, BS), 32T NR8157, M. Bodon & G. Vezzani leg. 20/08/2018, FLS (1 sh, MBC), FLU (20 sh, MZUF BC/62207; 24 sh, 4 juv sh, MBC).
- Lake Iseo, Sassabanek Beach, west of Iseo, 185 m a.s.l. (Iseo, BS), 32T NR8056, M. Bodon & G. Vezzani leg. 20/08/2018, FLU (36 sh, 87 juv sh, 1 juv sp, MBC).
- Lake Iseo, port of Clusane, 185 m a.s.l. (Iseo, BS), 32T NR7857, M. Bodon & G. Vezzani leg. 20/08/2018, FLU (2 sh, 1 juv sh, MBC).
- Lake Iseo, locality La Punta, Clusane, 185 m a.s.l. (Iseo, BS), 32T NR7857, M. Bodon & G. Vezzani leg. 20/08/2018, FLU (5 sh, MBC).
- Lake Iseo, Passeggiata Aviatori d'Italia, Sarnico, 185 m a.s.l. (Sarnico, BG), 32T NR7557, M. Bodon & G. Vezzani leg. 26/08/2019, CLU (32 sh, 8 juv sh, MBC), LEA (8 juv sh, MBC).
- Oglio River near Contrada Fosio, 180 m a.s.l. (Sarnico, BG), 32T NR7357, G. Nardi leg. 20/10/2018, FLU (20 sh, MZUF BC/60465; 1 juv sh, MBC), LEA (2 sh, 5 juv sh, GNC).
- Oglio River just upstream of Palazzolo sull'Oglio, 160 m a.s.l. (Palazzolo sull'Oglio, BS), 32T NR6950, M. Bodon & E. Bodon leg. 10/09/2003, CLU (3 sh, MBC; 5 sp).
- Oglio River, near the Piazzale Giovanni XXIII parking of Palazzolo sull'Oglio, 160 m a.s.l. (Palazzolo sull'Oglio, BS), 32T NR6849, G. Nardi leg. 20/10/2018, FLU (20 sh, 1 sp, MZUF BC/62208; 2 sh, MBC).
- Oglio River near Cascina Berlucchi, just downstream the bridge on the provincial road 11, between Calcio and Urago d'Oglio, 110 m a.s.l. (Calcio, BG), 32T NR6740, G. Nardi leg. 20/10/2018, CLU (3 sh, 8 sp, MZUF BC/60345; 2 juv sh, MBC).
- Oglio River 600 m upstream the bridge between Rudiano and Pumenengo, 100 m a.s.l. (Rudiano, BS), 32T NR6837, I. Niero leg. 21/07/2019, FLU (1 sp, INC), CLU (32 sp, 11 juv sp, INC).
- Oglio River between Cascina Malpaga and Cascina Tinazzo, 75 m a.s.l. (Orzinuovi, BS), 32T NR6930, G. Nardi leg. 20/10/2018, FLU (12 sh, 3 juv sh, GNC).
- Oglio River near Cascina Nantes, Bompensiero, 60 m a.s.l. (Villachiera, BS), 32T NR7023, C. De Carli leg. 01/11/1999, CLU (10 sh, 1 sp, GNC).
- Oglio River near Monasterolo, 50 m a.s.l. (Robecco d'Oglio, CR), 32T NR8114, M. Bodon & G. Vezzani leg. 17/08/2016, CLU (13 sh, 3 juv sh, MBC).
- Oglio River below the bridge on the state road 343, between Canneto and Piadena, 26 m a.s.l. (Canneto sull'Oglio, MN), 32T PR0700, G. Nardi leg. 20/10/2018, FLU (4 juv sh, GNC).

- Oglio River just downstream the motorway bridge south-east of Corte Tezzoglio, west of Marcaria, 16 m a.s.l. (Bozzolo, MN), 32T PQ1897, G. Nardi leg. 20/10/2018, FLU (17 sh, 3 juv sh, GNC).
- Chiusello Canal, locality Tavanelli, 600 m south-west of Acquanegra sul Chiese, 26 m a.s.l. (Acquanegra sul Chiese, MN), 32T PR1201, M. Bodon & S. Cianfanelli leg. 01/10/2017, FLU (1 sh, MBC; 17 sh, 1 juv sh, SCC; 76 sh, 16 juv sh, 30 sp, 5 juv sp, MZUF BC/59022).
- Chiusello Canal downstream Cascina la Fornace, 1 km south-west of Acquanegra sul Chiese, 25 m a.s.l. (Acquanegra sul Chiese, MN), 32T PR1101, M. Bodon & S. Cianfanelli leg. 01/10/2017, FLU (1 sh, 2 j sh, MBC; 4 sp, 1 juv sp, SCC).
- Trenzana irrigation Ditch, 2 km south-west of Chiari, 140 m a.s.l. (Chiari, BS), 32T NR7141, A. Dal Mas & F. Elvio leg. 03/08/2016, FLU (1 juv sp, ARPA-L).
- Canal between Cascina Bada di Sotto and Cascina Scovola, 75 m a.s.l. (Leno, BS), 32T NR9628, G. Nardi, A. Braccia, R. Frassine & L. Righetti leg. 29/05/2010, FLU (4 juv sp, GNC).
- Sale irrigation Ditch, east of Palosco, 150 m a.s.l. (Palosco, BG), 32T NR6648, S. Cerea & A. Sarzilla leg. 22/10/2018, CLU (20 sh, MZUF BC/62209; 3 sh, 3 sp, MBC; 1 sh, 2 sp, INC).
- Irrigation ditch near Cascinale Moracina, Perosso, 50 m a.s.l. (Castel Goffredo, MN), 32T PR1519, I. Niero leg. 22/05/2014, FLU (1 sh, INC).

Po River basin - Mincio River sub-basin

- Lake Garda, Le Rive, 65 m a.s.l. (Salò, BS), 32T PR1851, M. Bodon & G. Vezzani leg. 02/08/2019, FLU (20 sh, 8 juv sh, MBC).
- Lake Garda, Baia del Vento, 65 m a.s.l. (San Felice del Benaco, BS), 32T PR2250, M. Bodon & G. Vezzani leg. 02/08/2019, FLU (93 sh, 26 juv sh, MBC).
- Lake Garda, beach just west of Punta del Rio, Pieve Vecchia, 65 m a.s.l. (Manerba del Garda, BS), 32T PR2147, G. Nardi leg. 09/02/2002, FLU (17 sp, GNC).
- Lake Garda near Punta del Rio, Pieve Vecchia, 65 m a.s.l. (Manerba del Garda, BS), 32T PR2147, G. Nardi & A. Braccia leg. 09/02/2002, FLU (1 sh, INC), G. Nardi & A. Braccia leg. 24/10/2015, FLU (10 sh, ABC; 2 sh, 1 sp, GNC).
- Lake Garda, small port of Padenghe, 65 m a.s.l. (Padenghe sul Garda, BS), 32T PR1840, G. Nardi leg. 26/12/2017, FLU (1 sh, MBC; 3 sp, GNC).
- Lake Garda, Lonato Beach, 65 m a.s.l. (Desenzano del Garda, BS), 32T PR1938, F. Ciutti leg. 22/03/2017, FLS (1 sh, SCC).
- Lake Garda, natural park “San Francesco”, east of Rivoltella, 65 m a.s.l. (Desenzano del Garda, BS), 32T PR2436, G. Nardi leg. 26/07/2015, FLU (1 sh, GNC).
- Lake Garda, Brema Beach, Sirmione, 65 m a.s.l. (Sirmione, BS), 32T PR2536, M. Bodon & G. Vezzani leg. 17/04/2014, FLU (5 sh, MBC).
- Lake Garda near the restaurant Casa dei Pescatori, east side of Penisola di Sirmione, 65 m a.s.l. (Sirmio-

- ne, BS), 32T PR2537, M. Bodon & G. Vezzani leg. 17/04/2014, FLU (3 sh, 6 juv sh, MBC), LAR (3 sh, 1 juv sh, MBC).
 - Lake Garda, Cascina San Vito, east side of Penisola di Sirmione, 65 m a.s.l. (Sirmione, BS), 32T PR2637, M. Bodon & G. Vezzani leg. 17/04/2014, FLU (16 sh, 3 juv sh, MBC), LAR (3 sh, MBC).
 - Lake Garda, small port of Lugana, 65 m a.s.l. (Sirmione, BS), 32T PR2636, G. Nardi leg. 18/07/2005, FLU (2 sh, GNC).
 - Lake Garda, locality Cantarane, Punta Gro, 65 m a.s.l. (Sirmione, BS), 32T PR2735, M. Bodon & G. Vezzani leg. 18/04/2014, FLS (2 sh, 3 juv sh, MBC), FLU (8 sh, 2 juv sh, MBC), G. Nardi & R. Frassine leg. 02/03/2019, FLS (17 GNC), FLU (9 sh, 2 juv sh, GNC), LAR (3 sh, GNC).
 - Lake Garda, municipal beach of Punta Gro, 65 m a.s.l. (Sirmione, BS), 32T PR2835, M. Bodon & E. Bodon leg. 01/08/2006, FLU (8 sh, MBC; 500 sp).
 - Irrigation ditch 500 m east of Via dei Mulini, Volta Mantovana, 55 m a.s.l. (Volta Mantovana, MN), 32T PR3118, I. Niero leg. 22/05/2014, FLU (1 sh, INC).
 - Irrigation ditch mouthing into Mincio River near Strada Torre, south of Torre, 30 m a.s.l. (Goito, MN), 32T PR3213, I. Niero leg. 04/06/2019, FLU (3 sp, INC).
 - Mincio River at the bridge on the provincial road 21, Pozzolo, 40 m a.s.l. (Marmirolo, MN), 33T PR3318, I. Niero leg. 22/05/2014, FLS (1 sh, MZUF BC/60654), I. Niero leg. 04/06/2019, FLU (4 sp, INC), LAR (1 sp, INC).
 - Lake Mezzo, west shore, Mantova, 15 m a.s.l. (Mantova, MN), 32T PR4003, M. Bodon, & G. Nardi & G. Vezzani leg. 17/03/2019, LEA (2 sh, MBC).
 - Lake Mezzo, south-west shore, Mantova, 15 m a.s.l. (Mantova, MN), 32T PR4103, M. Bodon, & G. Nardi & G. Vezzani leg. 17/03/2019, FLU (1 sh, 11 juv sh, MBC), LEA (1 sh, MBC).
 - Begotta Brook between Piazza Colonna and Piazza Ca' Vecchia, Bosco della Fontana, 25 m a.s.l. (Marmirolo, MN), 32T PR3607, G. Nardi, A. Braccia & R. Frassine leg. 17/06/2012, FLU (3 sp, GNC), M. Bodon & G. Vezzani leg. 19/04/2014, FLU (2 sh, 1 juv sh, 9 juv sp, MBC).
 - Parcarella Ditch, outside Bosco della Fontana, east side towards Corte Barco, 25 m a.s.l. (Marmirolo, MN), 32T PR3706, G. Nardi, A. Braccia & R. Frassine leg. 17/06/2012, CLU (4 sp, MBC).
- #### TRENTINO-ALTO ADIGE
- ##### Adige River basin
- Lake at Passo di Lavazè, 1802 m a.s.l. (Varena, TN), 32T PS9136, M. Bodon & E. Bodon leg. 10/09/2004, FLS (1 sh, MZUF BC/60346).
- ##### Brenta River basin
- Lake Caldonazzo, Calceranica, 450 m a.s.l. (Caldonazzo, TN), 32T PR7496, M. Bodon & G. Vezzani leg. 10/08/2019, FLS (2 sp, 3 juv sp, MZUF BC/60347; 4 sp, 37 juv sp, MBC; 2 sp, 1 juv sp, INC).

VENETO

Lemene River basin

- Lemene River, Cavanella, Concordia Sagittaria, 1 m a.s.l. (Concordia Sagittaria, VE), 33T UL3266, I. Niero leg. 21/03/2019, FLU (6 sh, INC).
- Loncon River, Bonifica Loncon, 1 m a.s.l. (Concordia Sagittaria, VE), 33T UL2763, G. Favrin, G. Girardi & S. Menegon leg. 13/02/2018, FLU (1 sp, MBC, MZUF BC/59028), G. Favrin & G. Girardi leg. 11/05/2018, FLU (1 sp, MBC, MZUF BC/59029), F. Baldessin & G. Girardi leg. 15/10/2018, FLU (5 juv sp, MBC), F. Baldessin & G. Favrin leg. 06/02/2019, FLU (2 sp, 22 juv sp, MBC).

Piave River basin

- Piave River, docking of Kayak Club, San Donà di Piave, 3 m a.s.l. (San Donà di Piave, VE), 33T UL0856, G. Girardi & G. Favrin leg. 07/12/2017, FLU (2 sp, MBC).

Hydrographic network flowing into northern Laguna Veneta

- Dese River near Mulino, upstream Dese, 9 m a.s.l. (Martellago, VE), 33T TL7848, I. Niero leg. 25/02/2019, LEA (3 sp, INC).
- Dese River near Valeggio di Marocco, 3 m a.s.l. (Mogliano Veneto, TV), 33T TL8446, I. Niero leg. 13/03/2019, LEA (3 sh, 1 sp, INC).
- Small brook in front of Via Canove 81, Scorzè, 10 m a.s.l. (Scorzè, VE), 33T TL7352, I. Niero leg. 08/05/2008, LEA (1 juv sh, INC).
- Storto di Sant'Ambrogio Brook, Sant'Ambrogio, 20 m a.s.l. (Trebaseleghe, PD), 33T TL7254, I. Niero leg. 06/02/2019, FLU (1 sp, 4 juv sp, INC), LEA (3 sp, 4 juv sp, INC), I. Niero leg. 12/04/2019, LEA (5 sh, 19 sp, MZUF BC/60348; 1 juv sp, MBC).
- Sile River near Conca di Carafia, Bagaggiolo, 1 m a.s.l. (Roncade, TV), 33T UL0048, I. Niero leg. 09/03/2019, FLU (5 sp, INC).
- Sile River, locality Torre Caligo, 1 m a.s.l. (Iesolo, VE), 33T UL1345, G. Girardi & S. Menegon leg. 03/11/2011, FLU (4 juv sp, MZUF BC/59037), F. Baldessin, G. Girardi & S. Menegon leg. 11/03/2014, FLU (1 sp, 3 juv sp, MBC, MZUF BC/59036), F. Baldessin, G. Girardi & S. Menegon leg. 22/05/2014, FLU (2 juv sp, MZUF BC/59030; 1 juv sp, 1 sh, MBC, MZUF BC/59030), F. Baldessin, G. Girardi & S. Menegon leg. 03/11/2014, FLU (1 juv sp, MZUF BC/59035), G. Favrin, G. Girardi & S. Menegon leg. 01/03/2017, FLU (5 juv sp, MBC, MZUF BC/59038), G. Girardi & S. Menegon leg. 02/05/2017, FLU (3 juv sp, MBC, MZUF BC/59033), G. Favrin, G. Girardi & S. Menegon leg. 22/09/2017, FLU (2 juv sp, MZUF BC/59032), F. Baldessin & G. Favrin leg. 06/02/2019, FLU (10 sp, MZUF BC/59034; 1 sh, 7 sp, 2 juv sp, MZUF BC/59031; 8 sp, 6 juv sp, 1 sh, MBC), I. Niero leg. 19/06/2019, FLU (10 sp, INC).
- Taglio del Sile near Idrovora Lanzoni, Casa Nuova, Caposile, 1 m a.s.l. (Musile di Piave, VE), 33T UL0649, I. Niero leg. 09/03/2019, FLU (6 sp, INC).

- Taglio del Sile, locality Salsi, Capo Sile, 1 m a.s.l. (Musile di Piave, VE), 33T UL0850, I. Niero leg. 09/03/2019, FLU (5 sp, INC).
- Outfall of Sile River near Jesolo Beach, 0 m a.s.l. (Iesolo, VE), 33T UL1139, I. Niero leg. 20/07/1998, FLU (2 juv sh, INC).

Hydrographic network flowing into southern Laguna Veneta

- Brenta Waterway, Via Barbariga, downstream San Pietro di Stra, 5 m a.s.l. (Stra, VE), 33T TL6833, I. Niero leg. 11/03/2019, FLU (3 sp, INC), LEA (1 sh, 3 sp, INC).
- Brenta Waterway, state road 11 near the motorway viaduct downstream Valmarana, 4 m a.s.l. (Mira, VE), 33T TL7736, I. Niero leg. 11/03/2019, FLU (8 sp, INC), LEA (8 sp, INC).
- Brenta Waterway, Malcontenta, 1 m a.s.l. (Mira, VE), 33T TL8135, C. Celin, A. Lea & O. Siciliano leg. 16/03/2018, LEA (1 sp, MBC, MZUF BC/59048), L. Castelli, C. Celin, O. Siciliano & F. Turco leg. 10/09/2018, FLU (2 sp, MBC, MZUF BC/59039).
- Brenta Waterway, Moranzani, near the weir, 0 m a.s.l. (Mira, VE), 33T TL8434, I. Niero leg. 12/04/2019, FLU (2 sp, INC), LEA (8 sp, INC).
- Tergola River, Sant'Andrea di Codiverno, 10 m a.s.l. (Campodarsego, PD), 32T QR2942, O. Siciliano, L. Celin and A. Lea leg. 26/03/2019, LEA (30 sp, AR-PA-V).
- Tergola River near Luganega, Vigonza, 7 m a.s.l. (Vigonza, PD), 32T QR3435, I. Niero leg. 19/03/2019, LEA (2 sp, INC).
- Cavamento Drain along Via Cognaro, Pianiga, 5 m a.s.l. (Pianiga, VE), 33T TL6939, I. Niero leg. 19/03/2019, LEA (1 sp, INC).
- Drain along the road S.P. 49 near the crossing with Via Luganega, Barbariga, 5 m a.s.l. (Vigonza, PD), 33T TL6635, I. Niero leg. 19/03/2019, FLU (2 sp, INC).
- Caltana Drain near Via Caltana n. 230/A, between Caltana and Scaltenigo, 8 m a.s.l. (Mirano, VE), 33T TL7039, G. Nardi & A. Braccia leg. 23/09/2018, FLU (4 juv sh, 23 sp, 1 juv sp, GNC).

Brenta River basin

- Brenta River, bridge of Campo San Martino, 20 m a.s.l. (Campo San Martino, PD), 32T QR1947, I. Niero leg. 15/03/2019, FLU (5 sp, INC).
- Brenta River, bridge of Via Matteotti, Piazzola sul Brenta, 15 m a.s.l. (Piazzola sul Brenta, PD), 32T QR2144, I. Niero leg. 15/03/2019, FLU (4 sp, INC).
- Gorzone Canal, Zane Bridge, Carmignano, 5 m a.s.l. (Sant'Urbano, PD), 32T QR0802, C. Celin & O. Siciliano leg. 20/09/2018, FLU (1 sp, MBC), C. Celin, A. Lea & O. Siciliano leg. 28/02/2018, FLU (1 sh, 1 sp, MBC, MZUF BC/59026).
- Gorzone Canal, locality Buoro Vecchio, 1 m a.s.l. (Cavarzere, VE), 33T TL7601, L. Castelli, L. Celin, A. Lea & O. Siciliano leg. 30/03/2015, FLU (2 juv sp, MBC).

- Santa Caterina Canal, Vescovana, 4 m a.s.l. (Vescovana, PD), 32T QR1201, L. Castelli, C. Celin & A. Lea leg. 20/07/2018, FLU (2 juv sh, 2 juv sp, MBC).
- Bacchiglione River downstream the bridge of Montegalda, 20 m a.s.l. (Montegaldella, VI), 32T QR0935, I. Niero leg. 28/10/2003, FLU (2 juv sh, INC).
- Bacchiglione River at the confluence with Bacchiglione deviation, 5 m a.s.l. (Bovolenta, PD), 32T QR3117, I. Niero leg. 24/09/2008, FLU (1 sh, INC).
- Biancolino Canal, locality Mulino di Mezzavia, 10 m a.s.l. (Due Carrare, PD), 32T QR1921, I. Niero leg. 28/10/2003, FLU (3 sp, INC).
- Biancolino Canal at the bridge of Via delle Industrie, Pontemanco, 5 m a.s.l. (Due Carrare, PD), 32T QR2219, I. Niero leg. 28/10/2003, FLU (1 sp, INC).
- Biancolino Canal near Idrovora Madonnetta, east of Pontemanco, 5 m a.s.l. (Due Carrare, PD), 32T QR2319, I. Niero leg. 14/03/2008, FLU (1 sh, INC).
- Vigenzone Canal 300 m upstream the confluence with Cagnola Canal, 5 m a.s.l. (Due Carrare, PD), 32T QR2418, I. Niero leg. 24/09/2008, FLU (1 sh, INC).
- Bisatto Canal near Società Canottieri, Battaglia Terme, 8 m a.s.l. (Battaglia Terme, PD), 32T QR1819, I. Niero leg. 12/12/2006, FLU (2 sh, INC), I. Niero leg. 12/12/2006, LEA (1 sp, INC), I. Niero leg. 14/03/2008, FLU (1 sh, INC).
- Ceresone River at the bridge of Via Ceresone, Poiana di Granfion, Grisignano di Zocco, 20 m a.s.l. (Grisignano di Zocco, VI), 32T QR1340, I. Niero leg. 15/03/2019, FLU (5 sp, INC).
- Tesina River 100 m north of the join with Bacchiglione River, 25 m a.s.l. (Torri di Quartesolo, VI), 32T QR0341, I. Niero leg. 21/02/2008, FLU (1 sh, INC).
- Tesinella Canal at the bridge of Via Roma, Grisignano di Zocco, 20 m a.s.l. (Grisignano di Zocco, VI), 32T QR1139, I. Niero leg. 15/03/2019, FLU (2 sp, INC).
- Brenton Pighenzo Stream, Poggiana, 45 m a.s.l. (Castello di Godego, TV), 32T QR2463, L. Castelli, C. Celin, A. Lea, O. Siciliano & F. Turco leg. 28/09/2016, FLU (1 juv sp, MBC, MZUF BC/59027).

Adige River basin

- Adige River, Beverare, 3 m a.s.l. (San Martino di Venezze, RO), 32T QR3102, L. Castelli, C. Celin, O. Siciliano & F. Turco leg. 13/07/2016, FLU (3 juv sh, MBC).
- Adige River, locality La Busiola, Sant'Anna di Chioggia, 1 m a.s.l. (Chioggia, VE), 33T TL8702, I. Niero leg. 28/03/2019, FLU (2 sp, INC), LEA (2 juv sh, 2 sp, INC).
- Adige River, bridge on the state road Piovese, Cavarzere, 1 m a.s.l. (Cavarzere, VE), 33T TL6903, L. Castelli, C. Celin, A. Lea & O. Siciliano leg. 13/04/2016, FLU (1 juv sh, MBC).
- Outfall of Adige River near Corte Granaio, Fossone, 0 m a.s.l. (Rosolina, RO), 33T TL8802, I. Niero leg. 03/12/2001, FLU (3 sh, 1 sp, INC).
- Outfall of Adige River near Tenuta Busiola, Sant'Anna di Chioggia, 0 m a.s.l. (Chioggia, VE), 33T TL8803, I. Niero leg. 23/02/2002, LEA (1 juv sh, INC).

- Tione River, Grezzano, 35 m a.s.l. (Mozzecane, VR), 32T PR4619, L. Castelli, C. Celin, A. Lea & O. Siciliano leg. 12/10/2017, FLU (1 juv sp, MBC).
- Perimetrical ditch south-est of Azienda Agricola Villa Erbke, Mezzane di Sopra, 250 m a.s.l. (Mezzane di Sotto, VR), 32T PR6639, I. Niero leg. 13/07/2003, FLU (1 juv sp, INC).

Po River basin - Mincio River sub-basin

- Lake Garda north of Bardolino, 65 m a.s.l. (Bardolino, VR), 32T PR3646, F. Ciutti leg. 22/03/2017, FLS (1 sh, SCC).
- Lake Garda off shore of Cisano, 65 m a.s.l. (Bardolino, VR), 32T PR3442, I. Niero leg. 13/06/2019, FLS (10 sh, 15 sp, INC), FLU (3 sp, INC), LAR (10 sh, 1 juv sp, INC), LEA (10 sp, INC).
- Lake Garda, Lungolago Marconi north of Lazise, 65 m a.s.l. (Lazise, VR), 32T PR3541, I. Niero leg. 03/05/2008, FLS (2 sh, INC), FLU (3 sp, INC).
- Lake Garda between Lazise and Pacengo, 65 m a.s.l. (Lazise, VR), 32T PR3540, F. Ciutti leg. 22/03/2017, FLS (2 sh, 2 juv sh, SCC), FLU (2 sh, SCC).
- Lake Garda, locality Mattarana, Pacengo, 65 m a.s.l. (Lazise, VR), 32T PR3335, I. Niero leg. 04/06/2019, FLS (15 sh, INC), FLU (2 sh, 2 sp, INC), LAR (1 sh, 1 sp, INC), LEA (3 sh, 1 juv sh, GNC).
- Lake Garda, Ronchi Beach, 65 m a.s.l. (Castelnuovo del Garda, VR), 32T PR3335, M. Bodon & E. Bodon leg. 18/02/2012, FLS (5 sh, 8 juv sh, MBC), FLU (18 sh, 12 juv sh, MBC), G. Nardi & R. Frassine leg. 02/03/2019, FLS (5 sh, 1 juv sh, GNC), FLU (13 sh, GNC), LAR (5 sh, 1 juv sh, GNC).
- Lake Garda, Castelnuovo del Garda, 65 m a.s.l. (Castelnuovo del Garda, VR), 32T PR3235, F. Ciutti leg. 22/03/2017, FLS (1 juv sh, MZUF BC/59067), FLU (1 juv sh, MZUF BC/52150).
- Lake Garda, Lungolago Mazzini at Peschiera del Garda, 65 m a.s.l. (Peschiera del Garda, VR), 32T PR3233, I. Niero leg. 25/04/1999, FLU (1 sh, INC).
- Lake Garda, locality Fornaci, near the touristic village San Benedetto, 65 m a.s.l. (Peschiera del Garda, VR), 32T PR3034, M. Bodon & G. Vezzani leg. 18/04/2014, FLS (3 sh, MBC), FLU (7 sh, 3 juv sh, MBC), LAR (1 juv sh, MBC).
- Mincio River near the wharf of Società Canottieri, Peschiera del Garda, 65 m a.s.l. (Peschiera del Garda, VR), 32T PR3232, I. Niero leg. 22/06/2019, FLU (6 sp, INC), LAR (1 sp, MZUF BC/60655).

Po River basin - Canalbianco network

- Tartaro River, locality Codalunga, 10 m a.s.l. (Gazzo Veronese, VR), 32T PR6300, C. Celin, A. Lea & O. Siciliano leg. 28/03/2018, FLU (1 sp, MBC), LEA (1 sp, MBC).
- Menago River upstream Asparetto, 15 m a.s.l. (Cerea, VR), 32T PR7001, L. Celin & O. Siciliano leg. 15/04/2019, FLU (2 sp, ARPA-V), LEA (1 sp, ARPA-V).
- Menago River, Santa Teresa in Valle, 8 m a.s.l. (Cerea, VR), 32T PQ7598, L. Castelli, C. Celin, A. Lea, O. Si-

ciliano & F. Turco leg. 26/02/2018, FLU (1 sp, MBC, MZUF BC/59040).

- Bussè Canal, Roverchiara, 15 m a.s.l. (Roverchiara, VR), 32T PR7614, L. Castelli & A. Lea leg. 30/08/2018, LEA (2 sh, 1 sp, MBC, MZUF BC/59051), L. Castelli, C. Celin, A. Lea, O. Siciliano & F. Turco leg. 26/02/2018, LEA (1 sh, MBC).
- Bussè Canal, downstream the bridge of the provincial road 21, Oppeano, 10 m a.s.l. (Oppeano, VR), 32T PR7119, L. Castelli, C. Celin & F. Turco leg. 10/05/2018, LEA (1 sp, MBC, MZUF BC/59050).

Po River delta

- Po River, Polesella, 3 m a.s.l. (Polesella, RO), 32T QQ1782, M. Bodon & E. Bodon leg. 01/05/2008, FLU (19 juv sh, MBC), LEA (10 juv sh, MBC).
- Po River, Corbola, 2 m a.s.l. (Corbola, RO), 33T TK6987, I. Niero leg. 28/03/2019, FLU (1 sp, INC), LAR (3 sp, 3 juv sp, MZUF BC/60656; 1 sp, MBC; 10 sp, 3 juv sp, INC), LEA (1 juv sh, 4 sp, INC).
- Po River downstream Corbola, 2 m a.s.l. (Corbola, RO), 33T TK6988, M. Bodon & E. Bodon leg. 29/03/2005, FLU (5 sh, 3 juv sh, MBC), LEA (2 sh, 2 juv sh, MBC).
- Po River, Mazzorno, 2 m a.s.l. (Taglio di Po, RO), 33T TK7289, M. Bodon & E. Bodon leg. 29/03/2005, FLU (4 sh, 11 juv sh, MBC), LEA (2 sh, 31 juv sh, MBC), I. Niero leg. 02/04/2019, FLU (2 sp, INC), LAR (1 sp, INC), LEA (3 juv sh, 3 sp, INC).
- Po River upstream Taglio di Po, 2 m a.s.l. (Taglio di Po, RO), 33T TK7889, G. Desiato leg. 01/07/2006, LEA (2 sh, INC).
- Po River, locality Duo, downstream Taglio di Po, 1 m a.s.l. (Taglio di Po, RO), 33T TK8187, M. Bodon & E. Bodon leg. 29/03/2005, FLU (4 sh, 4 juv sh, MBC), LEA (4 sh, 34 juv sh, MBC).
- Po di Maistra River, Ca' Pisani, 1 m a.s.l. (Contarina, RO), 33T TK8982, I. Niero leg. 28/03/2019, FLU (1 sp, INC).
- Po di Venezia River, at difffluence with Po di Gnocca River, Molo Farsetti, 1 m a.s.l. (Taglio di Po, RO), 33T TK8781, M. Bodon & E. Bodon leg. 02/05/2008, FLU (29 juv sh, MBC), LEA (24 juv sh, MBC).
- Po di Venezia River, upstream Cà Venier, 1 m a.s.l. (Porto Tolle, RO), 33T TK8981, I. Niero leg. 26/02/2019, FLU (2 sh, 1 sp, INC), LEA (1 sh, 2 sp, INC).
- Po di Venezia River near Ca' Venier, 1 m a.s.l. (Porto Tolle, RO), 33T TK9081, I. Niero leg. 30/10/2004, LEA (1 juv sh, INC).
- Po di Venezia River, Ca' Zuliani, Porto Tolle, 1 m a.s.l. (Porto Tolle, RO), 33T TK9781, M. Bodon & E. Bodon leg. 29/03/2005, FLU (5 juv sh, MBC), LEA (8 juv sh, MBC), I. Niero leg. 28/03/2019, FLU (1 sp, INC), LAR (1 sh, INC), LEA (17 juv sh, INC).
- Po della Pila River between Ca' Zuliani and Pila, 1 m a.s.l. (Porto Tolle, RO), 33T TK9981, M. Bodon & E. Bodon leg. 02/05/2008, FLU (40 juv sh, MBC), LEA (33 juv sh, MBC).
- Outfall of Po della Pila River, Villaggio Pescatori

east of Pila, 0 m a.s.l. (Porto Tolle, RO), 33T UK0282, M. Bodon & E. Bodon leg. 02/05/2008, FLU (1 sh, 29 juv sh, MBC), LEA (17 juv sh, MBC).

- Po delle Tolle River, Polesine Camerini, Porto Tolle, 1 m a.s.l. (Porto Tolle, RO), 33T TK9779, I. Niero leg. 28/03/2019, FLU (2 sp, INC).
- Po delle Tolle River, Scardovari, 1 m a.s.l. (Porto Tolle, RO), 33T TK9974, I. Niero leg. 28/03/2019, LAR (1 sh, INC), LEA (3 sh, 10 juv sh, INC).
- Sacca dei Scardovari near Scardovari, 0 m a.s.l. (Porto Tolle, RO), 33T TK9974, M. Bodon & E. Bodon leg. 29/03/2005, FLU (10 juv sh, MBC), LEA (33 juv sh, MBC).
- Sacca dei Bottonera near Saccolina, 0 m a.s.l. (Porto Tolle, RO), 33T TK9467, M. Bodon & E. Bodon leg. 29/03/2005, FLU (5 juv sh, MBC), LEA (2 juv sh, MBC).
- Po di Gnocca River, Santa Giulia, 1 m a.s.l. (Porto Tolle, RO), 33T TK9268, M. Bodon & E. Bodon leg. 29/03/2005, FLU (1 sh, 12 juv sh, MBC), LEA (23 juv sh, MBC).
- Outfall of Po di Gnocca River near Santa Giulia, 0 m a.s.l. (Porto Tolle, RO), 33T TK9268, I. Niero leg. 23/02/2002, FLU (4 sh, INC).
- Po di Goro River, San Basilio, 1 m a.s.l. (Ariano nel Polesine, RO), 33T TK7579, I. Niero leg. 02/04/2019, FLU (2 sp, INC), LEA (4 sp, INC).

EMILIA-ROMAGNA

Po River basin

- Po River, railway viaduct of Piacenza, 40 m a.s.l. (Piacenza, PC), 32T NQ5589, M. Bodon & G. Vezzani leg. 17/08/2019, FLU (8 sh, MBC; 4 sh, ARPA-L).
- Po River north-east of Ragazzola, 30 m a.s.l. (Roccambianca, PR), 32T NQ9586, M. Bodon, G. Nardi & G. Vezzani leg. 16/03/2019, FLU (26 sh, 6 juv sh, MBC), LEA (3 sh, 4 juv sh, MBC), (2 sh, MBC).
- Po River north of Polesine Parmense, 30 m a.s.l. (Polesine Parmense, PR), 32T NQ8686, M. Bodon, G. Nardi & G. Vezzani leg. 16/03/2019, FLU (8 sh, 3 juv sh, 12 sp, MBC, MZUF BC/59018), LEA (5 sh, 1 juv sh, MBC).
- Po River below the bridge on the provincial road 358, north of Boretto, 20 m a.s.l. (Boretto, RE), 32T PQ2174, V. Bassi leg. 10/2017, FLU (3 sh, SQC), LEA (59 sh, SQC); G. Nardi leg. 16/09/2018, FLU (13 sh, GNC), LEA (1 juv sh, GNC).
- Po River, locality Borgo, Pescara, 4 m a.s.l. (Ferrara, FE), 32T QQ1277, M. Bodon & E. Bodon leg. 01/05/2008, FLU (1 sh, MBC), LEA (44 juv sh, MBC).

Po River basin - Secchia River sub-basin

- Borgazzo Canal near the Cartoccio Bridge, 20 m a.s.l. (Novellara, RE), 32T PQ3566, G. Mazza, F. Signorini & S. Bacchi leg. 23/09/2007, FLU (1 juv sp, MZUF BC/58855).
- Parmigiana Moglia Ditch, Bonifica Parmigiana, 15 m a.s.l. (Reggiolo, RE), 32T PQ5277, V. Bassi leg. 28/01/2005, FLU (2 sh, INC).

Po River delta and Valli di Comacchio

- Po di Volano River near Ca Grande, Passo di Pomposa, 1 m a.s.l. (Codigoro, FE), 33T TK7666, I. Perini leg. 01/08/2000, FLU (3 sh, GNC).
- Salghea Drain near Ca dei Grizola, Codigoro, 1 m a.s.l. (Codigoro, FE), 33T TK7366, I. Niero leg. 26/02/2019, FLU (2 sh, 1 sp, INC).
- Bettolino di Foce, Valli di Comacchio, 0 m a.s.l. (Comacchio, FE), 33T TK7749, M. Bodon & E. Bodon leg. 10/04/2012, LEA (1 juv sh, MBC).

Bevano River basin

- Outfall of Savio River, Lido di Classe, 0 m a.s.l. (Ravenna, RA), 33T TK8710, M. Bodon & E. Bodon leg. 08/04/2007, LEA (1 juv sh, MBC).
- Outfall of Bevano River, Bocca Bevano, 0 m a.s.l. (Ravenna, RA), 33T TK8615, M. Bodon & E. Bodon leg. 08/04/2007, FLU (1 juv sh, MBC), LEA (48 juv sh, MBC).
- Fosso Grande Drain east of Gambellara, Ravenna, 1 m a.s.l. (Ravenna, RA), 33T TK7413, I. Niero leg. 02/04/2019, FLU (2 sp, INC).

Savio River basin

- Outfall of Savio River, Lido di Classe, 0 m a.s.l. (Ravenna, RA), 33T TK8710, M. Bodon & E. Bodon leg. 08/04/2007, LEA (1 juv sh, MBC).

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Serchio River basin

- Irrigation ditch above the right bank of Serchio River, near San Michele di Moriano, 30 m a.s.l. (Lucca, LU), 32T PP2261, M. Bodon & S. Cianfanelli leg. 28/01/2017, LEA (7 sp, 13 sh, MZUF BC/51808; 6 sh, 13 juv sh, 22 juv sp, MBC; 30 sp, 330 juv sp, SCC).
- Irrigation ditch above the right bank of Serchio River, near San Quirico di Moriano, 30 m a.s.l. (Lucca, LU), 32T PP2260, G. Mazza & E. Tricarico leg. 29/07/2015, LEA (60 sp, MZUF BC/47715, BC/59042), A. Inghilesi & G. Stasolla leg. 03/08/2015, LEA (1 sh, 10 juv sh, MZUF BC/48151), M. Bodon & S. Cianfanelli leg. 28/01/2017, LEA (4 sh, 50 juv sh, 200 juv sp, MBC; 500 sh, 500 juv sh, SCC; 250 sh, 250 juv sh, MZUF BC/59043).
- Serchio River downstream the bridge between San Marco, Lucca, and Monte San Quirico, 15 m a.s.l. (Lucca, LU), 32T PP2157, M. Bodon & S. Cianfanelli leg. 25/05/2019, LEA (4 sh, 6 sp, 1 juv sp, MBC; 5 sp, INC).
- Serchio River upstream Ponte San Pietro, Nave, 13 m a.s.l. (Lucca, LU), 32T PP1657, M. Bodon & S. Cianfanelli leg. 28/01/2017, LEA (3 sh, 1 juv sh, MBC; 2 sh, SCC).
- Serchio River downstream the motorway viaduct Lucca-Viareggio, downstream Ponte San Pietro, Montuolo, 10 m a.s.l. (Lucca, LU), 32T PP1655, M. Bodon & S. Cianfanelli leg. 28/01/2017, LEA (2 sh, MBC; 4 sh, SCC).
- Serchio River P.te Nuovo, S.ta Maria a Colle, 10 m

a.s.l. (Lucca, LU), 32T PP1655, P. Ercolini leg. 2013, LEA (10 sh, PEC); P. Ercolini leg. 2014, LEA (34 sh, 10 juv sh, PEC), P. Ercolini leg. 07/2017, LEA (10 juv sp, MBC, MZUF BC/59044), P. Ercolini & G. Baldaccini leg. 14/07/2018, LEA (11 juv sp, MBC, MZUF BC/59045); P. Ercolini & G. Baldaccini leg. 21/07/2018, LEA (16 sh, 4 juv sh, PEC; 26 juv sp, MBC, MZUF BC/59046); P. Ercolini & G. Baldaccini leg. 28/07/2018, LEA (3 juv sp, MZUF BC/59047; 56 juv sp, MBC, MZUF BC/59047).

- Serchio River downstream the bridge in front of Ripafratta, 5 m a.s.l. (Vecchiano, PI), 32T PP1352, M. Bodon & S. Cianfanelli leg. 02/09/2017, LEA (2 sh, MZUF BC/60349; 2 sh, MBC; 2 sp).
- Outfall of Serchio River near the sea, 1 km northwest of Casone di Marina, 0 m a.s.l. (Vecchiano, PI), 32T PP0248, M. Bodon, S. Cianfanelli, G. Vezzani & M. Calcagno leg. 04/11/2018, LEA (1 juv sh, MBC).
- Fosso Biancalana near the join with Serchio River, Casone di Marina, 0 m a.s.l. (Vecchiano, PI), 32T PP0248, M. Bodon & S. Cianfanelli leg. 04/11/2018, FLU (3 sh, MBC), LEA (21 sh, 7 juv sh, MBC; 1 sh, SCC).

Hydrographic network between Serchio and Arno rivers

- Ditch along Viale Europa 237, provincial road 29, Marlia, 35 m a.s.l. (Capannori, LU), 32T PP2560, I. Niero leg. 04/11/2017, LEA (1 sp, INC).
- Ripafratta State Canal at the bridge of Orzignano, 4 m a.s.l. (San Giuliano Terme, PI), 32T PP1448, M. Bodon, S. Cianfanelli, G. Vezzani & M. Calcagno leg. 07/10/2018, LEA (2 juv sp, MBC; 5 sh).
- Ripafratta State Canal, along the state road 12, at the bridge on Via delle Sorgenti, south of San Giuliano Terme, 2 m a.s.l. (San Giuliano Terme, PI), 32T PP1646, A. Inghilesi leg. 18/08/2016, LEA (11 sh, 1 juv sh, 1 sp, 2 juv sp, MZUF BC/52630), S. Cianfanelli & M. Calcagno leg. 22/10/2017, LEA (23 sh, 8 juv sh, SCC; 160 sh, 26 juv sh, 13 sp, MZUF BC/53143), M. Bodon & S. Cianfanelli leg. 23/09/2018, LEA (14 sh, 64 juv sh, 7 sp, 21 juv sp, MBC).
- Drain along the state road 12, in front of the bridge in Via delle Sorgenti, south of San Giuliano Terme, 2 m a.s.l. (San Giuliano Terme, PI), 32T PP1646, M. Bodon & S. Cianfanelli leg. 23/09/2018, LEA (22 sp, MZUF BC/60350; 10 sh, 10 sp, ARPA-L; 190 sh, 30 juv sh, 22 sp, 200 juv sp, MBC), M. Bodon & S. Cianfanelli leg. 07/10/2018, LEA (300 sh, 300 juv sh, SCC).

Arno River basin

- Arno River at the bridge of Via Ponte Nuovo, between Signa and Ponte a Signa, 30 m a.s.l. (Signa, FI), 32T PP6848, S. Cianfanelli & M. Calcagno leg. 29/09/2019, FLU (2 sh, 1 juv sh, 2 sp, SSC).
- Arno River, Uliveto Terme, 5 m a.s.l. (Vicopisano, PI), 32T PP2139, M. Bodon & S. Cianfanelli leg. 23/09/2018, FLU (1 sp, 1 juv sp, MZUF BC/60351; 1 juv sh, 1 sp, 1 juv sp, MBC).
- Arno River at the bridge between Zambra and

Caprona, 4 m a.s.l. (Cascina, PI), 32T PP2040, M. Bordon & S. Cianfanelli leg. 23/09/2018, FLU (1 sh, MZUF BC/60352; 2 sh, 10 juv sh, MBC; 3 sh, SCC), LEA (2 juv sh, MBC; 3 sh, 3 juv sh, SCC).

Arno River basin - Bisenzio River sub-basin

- Bisenzio River, locality Santa Lucia, Prato, 70 m a.s.l. (Prato, PO), 32T PP7063, S. Cianfanelli & M. Calcagno leg. 21/10/2018, LEA (2 juv sh, 2 sp, SCC).
- Bisenzio River, locality Gli Abatoni, Prato, 65 m a.s.l. (Prato, PO), 32T PP6963, S. Cianfanelli & M. Calcagno leg. 21/10/2018, LEA (1 sp, SCC).
- Bisenzio River 3,2 km south-south-east of Prato, 35 m a.s.l. (Prato, PO), 32T PP7058, S. Cianfanelli & M. Calcagno leg. 08/09/2018, FLU (2 sh, 3 juv sh, SCC), LEA (200 sh, 1 sp, SCC).
- Bisenzio River, Mezzana, 35 m a.s.l. (Prato, PO), 32T PP7057, L. Lapi leg. 25/03/2016, FLU (2 sp, MZUF

- BC/59999), LEA (2 sp, MZUF BC/60000), L. Lapi leg. 10/06/2016, FLU (1 sp, MZUF BC/60001), LEA (1 sp, 2 juv sp, MZUF BC/60002), L. Lapi leg. 12/10/2016, LEA (1 juv sh, MZUF BC/60003), L. Lapi leg. 21/04/2017, LEA (1 sp, MZUF BC/60004), L. Lapi leg. 06/07/2017, FLU (1 juv sp, MZUF BC/60005).
- Bisenzio River, locality Renai, Signa, 30 m a.s.l. (Signa, FI), 32T PP6950, L. Lapi leg. 10/10/2016, LEA (2 sp, MZUF BC/60006), S. Cianfanelli & M. Calcagno leg. 21/10/2018, FLU (15 juv sp, SCC).
- Bisenzio River, 300 m upstream the join with Arno River, Signa, 30 m a.s.l. (Signa, FI), 32T PP6949, S. Cianfanelli & M. Calcagno leg. 21/10/2018, FLU (25 sh, 18 juv sh, SCC), LEA (18 juv sh, 1 sp, SCC), S. Cianfanelli & M. Calcagno leg. 29/09/2019, FLU (1 sp, MZUF BC/60646; 30 sh, 1 juv sh, 9 sp, 6 juv sp, SCC), LEA (2 juv sh, SCC).

Melanella orientalis n. sp. (Gastropoda: Eulimidae) from the Eastern Mediterranean

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Abstract

The new species *Melanella orientalis* is described based on 24 shells found in shell grit taken in various localities of Eastern Mediterranean (Djerba, Cyprus, Karpathos, Samos, Alexandria) at a depth between 0 and 45 m. The new species is characterized by last whorl expanded at the periphery, the wide aperture and the outer lip profile. Differences from *Melanella orthophyes* (Sturany, 1903) from Red Sea, as well as Mediterranean and Indo-Pacific species are discussed.

Key words

Melanella orientalis, Eastern Mediterranean, n. sp.

Riassunto

[*Melanella orientalis* n. sp. del Mediterraneo orientale]. Viene descritta la nuova specie *Melanella orientalis* sulla base di 24 esemplari rinvenuti in varie località del Mediterraneo orientale (Djerba, Cipro, Karpathos, Samos, Alessandria d'Egitto) a profondità tra 0 e 45m. La nuova specie è caratterizzata dall'ultimo giro espanso alla periferia, l'ampia apertura e il profilo del labbro esterno. Sono discusse le differenze da *Melanella orthophyes* (Sturany, 1903) del Mar Rosso e da altre specie mediterranee ed Indo-Pacifiche.

Parole chiave

Melanella orientalis, Mediterraneo orientale, n. sp.

Introduction

Nineteen species of the genus *Melanella* Bowdich, 1822 are currently listed for the Mediterranean sea (Sistematica Mediterranea), showing a variety of forms. The Eulimids have been dealt with by Warén (1984), while the Mediterranean species have been discussed/illustrated by Giannuzzi Savelli et al. (1999), Cossignani & Ardovini (2011), Gofas (2011), while Fretter & Graham (1982) well illustrate and discuss the species from Britain and Denmark, most of which are also present in the Mediterranean. Species from Gabès Gulf have been dealt with by Cecalupo et al. (2008).

Among the several alien molluscan species (Zenetos et al., 2010; Zenetos & Galanidi, 2020) a single Eulimid, *Sticteulima lentiginosa* (A. Adams, 1861) was listed by Zenetos et al. (2010) as "casual". To be noted that Eulimids are parasitic of ophiuroids, holothurians and echinoderms. Some genera, as *Melanella*, may move from one host to another, while others (e.g. *Pelseneeria*) are permanently attached to the host (Fretter & Graham, 1982; Gofas, 2011). Therefore even if some Melanellids have planktotrophic development (Warén, 1984) and free-swimming larvae could cross the Suez Canal, possibly there is a further difficulty due to the lack of usual species host in the new area. In the hypothesis that this is an alien species, the finding of specimens in various localities (Fig. 1), indicates that it is already well established in the Mediterranean, and was not yet detected in previous works. An extensive comparison

with Mediterranean and Indo-Pacific species, convinced us to describe it as new species.

Material and methods

This species has been found in various localities in Central and Eastern Mediterranean. The sediment was taken manually by snorkeling or immersion in ARA, using very fine mesh screens, in the below listed localities.

Cyprus - Larnaka, about 8 km east of the town, near Dhekelia Power Station (34° 58' 51.708" N, 33° 44' 8.865" E), in about 1.5 kg of sediment collected on March 2016 in Posidonia intermattes, depth 4 m. Point A of Fig. 1.

Egypt - Abukir (east of Alexandria) (31° 19' 13.462" N, 30° 3' 28.252" E) in about 1 kg of sediment collected on April 2016 in tide pools. Point B of Fig. 1.

Greece - Achata bay (south-eastern coast of Karpathos island) (35°33'31.201" N; 27°12'16.466"E), depth 33 m. Samples were manually collected at the base of rocky wall reaching the sea surface, therefore material from upper levels could be mixed up. Point C of Fig. 1. Kerveli (eastern coast of Samos island, Greece), depth 45 m (coordinates 37°44'6.616" N; 27°2'19.594" E). Point E of Fig. 1.

Tunisia - Djerba island, in shell grit collected near the ship wrench of "Alga" (33°50'63" N, 11°06'57" E), depth 18-20 m. Point D of Fig. 1.



Fig. 1. Distribution of *Melanella orientalis* n. sp.

Fig. 1. Distribuzione di *Melanella orientalis* n. sp.

Abbreviations and acronyms

SEM: scanning electron microscope; W: maximum width (in mm); H = maximum height (in mm); D = total diameter of the protoconch (in μm);

coll. = collection; Museum of Natural History, Wien (NHMW); FAP = Franco Agamennone (Pescara); FSL = Franco Siragusa (Livorno); PMF = Micali Pasquale (Fano).

Systematic

Family Eulimidae Philippi, 1853

Genus *Melanella* Bowdich, 1822

Melanella orientalis n. sp.

Type material and Material examined

Holotype (H = 2.5 mm) type locality, deposited at the Museum Natural History in Wien, n° NHMW-MO-113605. **Fig. 2 C-D.**

Paratype 1 (H = 3.4 mm) Djerba island (Tunisia), 18-20 m depth (FAP), **Fig. 2 A-B.**

Paratype 2 (H = 3.0 mm) type locality (FAP).

Paratype 3 (H = 2.0 mm) type locality (PMF).

Paratype 4 (H = 2.8 mm) type locality (FSL).

Paratype 5 (H = 2.2 mm) type locality (FSL).

Other examined material

Larnaka (Cyprus): 2 specimens (largest is 4.15 mm high) (FAP). Abukir (Egypt): 3 specimens (largest is 3.45 mm high) (FAP). Achata bay (Karpathos island, Greece): 12 specimens (largest is 4.1 mm high) (FAP, PMF). Kerveli (Samos island, Greece): 1 specimen (3.05 mm high) (PMF). Djerba island (Tunisia): 1 specimen (4.2 mm high) (FAP).

Type locality

Achata bay (south-eastern coast of Karpathos island) (35°33'31.201" N; 27°12'16.466"E), depth 33 m.

Etymology

The species name originate from its geographical distri-

bution in the Mediterranean, that seems to cover the eastern part only.

Description

Shell straight, conical, vitreous, with a large aperture. The larval shell is more cylindrical with respect to the teleoconch, and consists of about 2.5, smooth, slightly convex whorls. The transition protoconch-teleoconch is considered the first incremental scar. The apex is slightly eterostrophic (**Fig. 2B, D**).

The holotype has about five very slightly convex, smooth whorls, marked by one incremental scar at the fourth teleoconch whorl. Another specimen shows two incremental scars distant about 0.75 whorls, placed roughly at the fourth teleoconch whorl. Suture well marked for the genus. False suture clearly visible, situated at about 1/3 whorl from adapical suture. Last whorl expanded at the periphery. The aperture is large, pyriform, protruding outside the plane of penultimate whorl, adapically acute, abapically expanded and regularly convex. Columella straight, opisthocline. Columellar lip thickened. Parietal callus thin but extended up to connection with the external lip. Outer lip is sinuated, starting slightly opisthocline and projecting in the central part. In the holotype last whorl occupies about 53% of total height, aperture about 40% of total height. In larger specimens (**Fig. 2 A, B**) the last whorls occupies roughly same percentage, while the aperture occupies about 36% of total height.

Distribution

At present the species is widely distributed in the Eastern Mediterranean, reaching westwards the Gulf of Gabes. The bathymetric range of the findings is very wide: from tide pool at Abukir, to 45 m at Kerveli.

Discussion

Melanella orientalis may be easily separated from the Mediterranean *M. petitiana* (Brusina, 1869) for the larger aperture, higher and slightly convex whorls, and thinner shell. All the other Mediterranean species are more different and do not need to be compared.

Furthermore, a research was carried out aimed at identifying the possible belonging of the specimens under study to the alien fauna coming from Indo-Pacific ocean.

Eulima orthophyes Sturany, 1903 was described on a single specimen collected in the Red Sea at Gul Mohammad (near Jeddah), possibly at low depth. The holotype, deposited at Natural History Museum Wien (n° 37810) was figured by Albano et al. (2017). Original description is in German, translated in Albano et al. (2017) as follow "The smooth, very shiny, white-colored shell is almost straight; the apex is minimally inclined to the right. There are 11 whorls, which are separated by a fili-form suture; the size of the shell is 7.4 mm high and 2.6

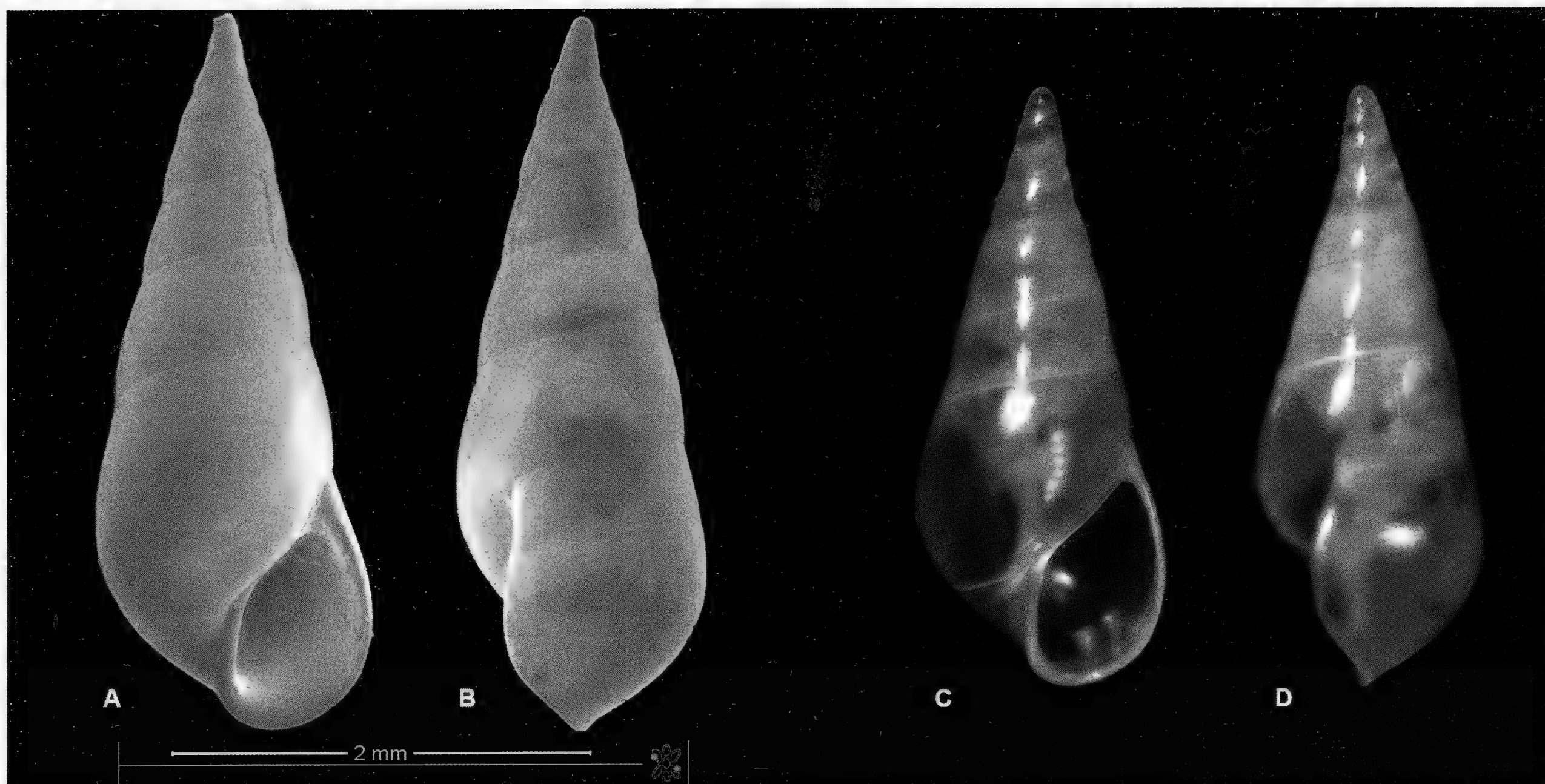


Fig. 2. A-D *Melanella orientalis* n. sp. **A-B**. Paratype 1, H = 3.4 mm, Djerba (Tunisia), 18-20 m; **A** frontal view, **B** side view. **C-D**. Holotype (NHMW-MO-113605), H = 2.5 mm, Achata bay (Karpachos island, Greece), depth 33 m.

Fig. 2. A-D *Melanella orientalis* n. sp. **A-B**. Paratipo 1, H = 3,4 mm, Djerba (Tunisia), 18-20 m; **A** vista frontale, **B** vista laterale. **C-D**. Olotipo (NHMW-MO-113605), H = 2,5 mm, Achata bay (isola di Karpachos, Grecia), profondità 33 m.

mm wide, the mouth is about 2.5 mm high. The form of the new species resembles *Stylifer acicula* Gould, the shell shape is similar to *E. solidula* Adams and Reeve from the Sandwich Islands (Berlin Museum)". The new species differs from *E. orthophyes* for the thin-translucent, instead of rather thick shell (P. G. Albano pers. com., 10 Feb. 2010), the different profile of the aperture in side view (sinuated instead of regularly arched) and the lack of slight bending of the protoconch. A check has been done with the two species indicated by Sturany as similar to *E. orthophyes*. The new species differs from *Melanella acicula* (Gould, 1850) from Fiji islands, figured in Hori & Matsuda (2000), for the wider angle of spire, larger aperture projecting from spire profile and smaller dimensions; it differs from *M. solidula* (Adams & Reeve, 1850) from Japan, figured in Hori & Matsuda (2000), because it is much smaller, not solid and with a much larger aperture.

No other similar species have been found in Bosch et al. (1995), Hori & Matsuda (2000), Rusmore-Villaume (2008), Edelman-Furstenberg & Faershtein (2010), Blatterer (2019) and works of James Cosmo Melvill on mollusca of Eastern Arabia and India.

It show some resemblance with *Sticteulima wareni* Engl, 1997, from Cape Verde and Canary islands (Hernández et al., 2011), but clearly differs for the almost double size with same number of whorls, narrow spire, more depressed whorls, rastremated apical whorls and sub-rhomboidal instead of sub-elliptical aperture.

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First report of *Mytilopsis leucophaeata* (Conrad, 1831) (Bivalvia: Dreissenidae) from the coasts of Italy

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Abstract

Mytilopsis leucophaeata (Conrad 1831) is a species alien to the Mediterranean, native to brackish environments of the western Atlantic, considered an opportunistic species and a slow colonizer with low dispersal capacity (Kennedy, 2011b), but potentially harmful to the habitats where it settles. In areas where it has been accidentally introduced, it has often caused significant economic damage to infrastructure that becomes encrusted with thousands of individuals (Eeuwes, 2018). Its presence in Europe has been documented since 1835, but it has never hitherto been reported from the central and eastern Mediterranean. This is the first record of the mollusc from the Italian coasts, namely the province of Venice, where empty valves and living specimens have both been found. These findings suggest that *M. leucophaeata* has started to colonize the Brenta river basin or in any case the upper Adriatic Sea.

Key words

Mytilopsis leucophaeata, Dreissenidae, upper Adriatic Sea, alien species, distribution.

Riassunto

Mytilopsis leucophaeata (Conrad, 1831), è una specie aliena per il Mediterraneo, originaria degli ambienti salmastri dell'Atlantico occidentale, considerata una specie opportunistica ed un colonizzatore lento con una bassa capacità di dispersione (Kennedy, 2011b), ma potenzialmente molto dannosa per gli habitat dove si insedia. Nelle zone dove è stato accidentalmente introdotto spesso ha causato ingenti danni economici alle infrastrutture e ai manufatti che vengono ricoperti da migliaia di individui (Eeuwes, 2018). La sua presenza in Europa è documentata dal 1835, ma fino ad ora non era mai stata segnalata nel Mediterraneo centrale e orientale. Questa è la prima segnalazione di questo mollusco per le coste italiane, in particolare sul litorale della provincia di Venezia, dove sono state trovate sia valve vuote sia esemplari viventi. Questi ritrovamenti lasciano supporre che *M. leucophaeata* abbia iniziato a colonizzare il bacino del fiume Brenta o comunque l'alto Adriatico.

Parole chiave

Mytilopsis leucophaeata, Dreissenidae, alto Adriatico, specie aliene, distribuzione.

Introduction

Mytilopsis leucophaeata (Conrad, 1831) is a bivalve of the family Dreissenidae, order Myida, also known as dark false mussel or Conrad's false mussel. The shell is mussel-shaped, oblong, subcylindrical, inequivalve and depressed, compressed towards the dorsal margin and slightly dilated at the posterior end of the ligament. The umbones are pointed and slightly curved, and the right valve is larger than the left, a character which is more evident in ventral margin view. The shell is generally brown with whitish areas. Juveniles sometimes have zig-zag colouring. The periostracum is thin and brown, often abraded, and occasionally has elongated filament lines, disposed radially from the umbones. The interior of the shell is whitish and pearly in the pallial and extra-pallial regions. Pallial line and muscle scars are glossy; posterior muscle scars do not extend beyond the upper limit of the ligament area. There is a typical septum on the side of the umbones, site of the anterior retractor muscle, and a small rounded triangular tooth where the

anterior divaricator muscle attaches on the dorsal side near the septum.

The area of origin of *M. leucophaeata* is the western Atlantic, especially the Gulf of Mexico from Tampico (Mexico) to Florida (USA) and along the Atlantic coast to Chesapeake Bay (Eeuwes 2018, Kennedy 2011a, Marelli & Gray, 1983). Its original environment is brackish estuaries and coastal lagoons but it can also be found in continental water bodies which it colonizes via rivers and canals (Kennedy 2011b).

It is currently reported from many parts of the world: the coasts of Brazil, the North Sea (Belgium, Netherlands, England, Wales, Germany), the Baltic Sea (Poland, Lithuania, Russia, Sweden, Finland), the Black Sea (Ukraine), the Atlantic and Mediterranean coasts of Spain and France, and the Caspian Sea (Iran) (Eeuwes 2018). It has not previously been reported from the coasts of Italy or in the Adriatic.

Mytilopsis sallei Recluz, 1849, is another bivalve reported from the Mediterranean at Haifa (Israel) by Galil & Bogi (2009). *Mytilopsis leucophaeata* (Conrad, 1831) is dis-

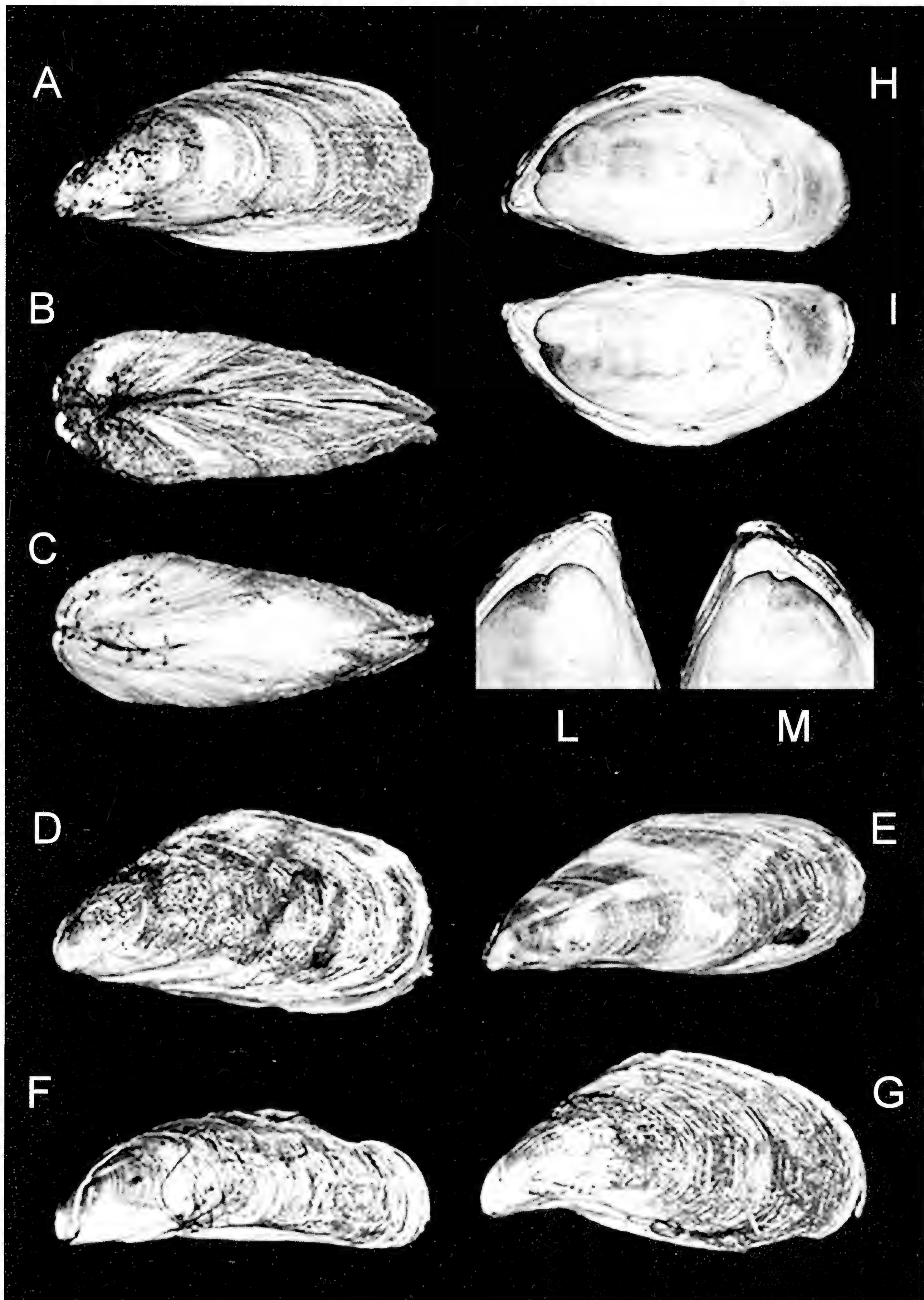


Fig. 1. *Mytilopsis leucophaeata* Lido di Pellestrina (Venezia) **A-C.** 21.7 mm; **H, I.** 21.10 mm; **L, M.** detail of the hinge. **D.** 20.80 mm; **E.** 22.4 mm. **F.** 19.6 mm; **G.** 23 mm.

Fig. 1. *Mytilopsis leucophaeata* Lido di Pellestrina (Venezia) **A-C.** 21,7 mm; **H, I.** 21,10 mm. **L, M.** dettaglio della cerniera. **D.** 20,80 mm; **E.** 22,4 mm; **F.** 19,6 mm; **G.** 23 mm.

tinguished from *Mytilopsis sallei* Recluz, 1849, by virtue of different proportions between shell length and width (Marelli & Gray, 1983), a different form of septum and posterior muscle scars that do not extend beyond the area of the ligament (Marelli & Gray, 1983).

Biology

Mytilopsis leucophaeata is a filtering bivalve mollusc that feeds on zooplankton, phytoplankton and suspended organic and inorganic matter. It is very adaptable to different conditions of temperature (4-25°C) and salinity (2-20 PSU) (Eeuwes 2018, Kennedy 2011b, Zhulidov et al. 2015). In its native habitat, it occurs in oligohaline and mesohaline water bodies such as coastal lagoons and estuaries, ascending water courses, where it is unable, however, to reproduce for lack of salt water (Eeuwes

2018). Its invasive potential is greatest at salinities in the 5-12 PSU range. Where introduced, it lives in the same environments, but has also adapted to low temperatures. Its spread beyond its original distribution is well documented and was presumably due to passive transport of larvae in the ballast water of ships or to adults encrusting the hulls of marine and river vessels. It can also occasionally be transported on the shells of cultivated oysters marketed in distant places (Van der Gaag et al. 2016, Wolff & Reise, 2002). Its spread in Europe began in 1835 when it first colonized the waters of Belgium and then Wales, and subsequently all of northern Europe, presumably along the navigation canal network (Eeuwes 2018). Although in many parts of Europe colonized by *M. leucophaeata* water temperatures are much lower than in its native tropical and subtropical waters, the bivalve has shown a great capacity for adaptation, initially coloniz-



Fig. 2. Live specimens of *Mytilopsis leucophaeata* attached to a fragment of marsh reed washed up at Lido di Sottomarina (Chioggia-VE).
Fig. 2. Esemplari viventi di *Mytilopsis leucophaeata* attaccati a un frammento di canna palustre portata a riva al Lido di Sottomarina (Chioggia-VE).

ing coastal areas heated by the cooling water of nuclear power stations (Zhulidov et al. 2015) and other industrial plants, and gradually adapting to life at increasing distances from the latter. Its presence in the discharge tubes of these plants is an enduring problem which is difficult to solve: here it finds ideal temperatures for reproduction so that populations can grow rapidly.

The reproductive season of *M. leucophaeata* lasts about 5 months, from May-June to October, if the water temperature is not below 13°C. To trigger reproduction, seawater is necessary, which is why the bivalve never migrates far up water courses (Van der Gaag et al. 2014). Adult specimens accidentally transported into fresh water can survive but not reproduce. The larval phase lasts about 2 weeks, and individuals are estimated to live 4-4.5 years (Van der Gaag et al., 2017).

M. leucophaeata can form very large colonies, although in its original environment its proliferation is controlled by natural predators of larvae and adults. In Europe, Asia and Brazil, where it was accidentally introduced by humans and where possible predators of adults may not yet have learned to recognize it as prey, and presumably due to the absence of brackish water bivalve competitors, its population dynamics are different, and it may form colonies numbering millions of individuals (Eeuwes 2018).

Material examined

The specimens described in the present study, washed up on beaches within a few metres of the water, were collected on three occasions. A first specimen, a single valve, was found on 20/11/2013 at the northern end of the beach at Sottomarina, a seaside locality in the Municipality of Chioggia (VE). On 25/03/2018, dozens of specimens attached to a trunk were found washed up on the beach of Pellestrina (VE) at the northern end of the town. The shells were all integral but open and empty. About 60 specimens, with shells ranging in length from 24.1 mm to 10.5 mm (mean 19 mm), width 12 mm to 5.4 mm (mean 8.7 mm) and thickness 10.2 mm to 4.5 mm (mean 7.6 mm), were collected. The specimens shown in Fig. 1 belong to this group of shells.

The third and most significant finding (Fig. 2) occurred on 28/07/2019, again at Sottomarina (VE). After a coastal storm, a 25-cm fragment of a large grass, probably a marsh reed, bearing six live adult specimens and one juvenile (length 4 mm, width 2.5 mm, thickness 2 mm), was washed up 100 m from the rocks forming the left bank of the estuary of the Brenta river. One adult was particularly large (length 23.9 mm, width 10.9 mm, thickness 9.9 mm); the dimensions of the others were within the range of the first specimens.

Discussion

The finding of live specimens suggests that although the colony has not yet been located, it may not be far from where the specimens were found, possibly in the reed beds of the estuary itself or of tributaries of the Brenta. The closest report of *M. leucophaeata* in the Medi-

terranean has hitherto been from the coasts of France (Girardi, 2003); apart from a report of not better identified specimens of the genus *Mytilopsis* from Romagna (Camerani, 2009), this seems to be the first report from Italy. *Mytilopsis leucophaeata* is a very adaptable alien species, which despite being considered a slow colonizer with low dispersal capacity (Kennedy 2011b, Zhulidov et al., 2015), can potentially establish in any brackish water body, damaging coastal industrial plant and harbour infrastructure, and in particular obstructing cooling water discharge pipes.

Although the mollusc is a very efficient filterer, it paradoxically causes eutrophication of the water body while increasing water transparency, favouring algal proliferation and altering ecosystem balance (Eeuwes, 2018). Little is known about its impact on the biodiversity of the systems it colonizes.

The stranded trunk to which the shells described here were attached must have been in the sea for a long time. It was not possible to identify the species or where it came from. It may have been carried by currents from distant coasts or have come from northern Adriatic lagoons or estuaries such as those of the Brenta or Piave. Perusal of navy hydrographic institute charts of Adriatic surface currents suggests that detritus reaching the coasts of the province of Venice comes from the extreme north of the Adriatic or the coasts of Slovenia and Croatia, rather than from the central Adriatic. The size of the shells found suggests that the specimens were adults and that they came from an established colony, as confirmed by the finding of a juvenile (Fig. 2).

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Subfamily Cardiinae Lamarck, 1809
Genus *Acanthocardia* Gray, 1853
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Cardium indicum Lamarck, 1819
(Fig. 1. A-D, Fig. 2. C)

Cardium hians Brocchi, 1814: p. 508, tav. 13, fig. 6 (non Spengler, 1799).
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SALAS C., 1996. Marine Bivalves from off the Southern Iberian Peninsula collected by the Balgim and Fauna 1 expeditions. *Haliotis*, **25**: 33-100.
GRILL B. & ZUSCHIN M., 2001. Modern shallow- to deep-water bivalve death assemblages in the Red Sea – ecology and biogeography. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **168**: 75-96.
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